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Using temperature profiles to investigate the hyporheic zone in an agricultural drainage ditch

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USING TEMPERATURE PROFILES TO INVESTIGATE THE HYPORHEIC ZONE IN AN AGRICULTURAL DRAINAGE DITCH

by

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This thesis, submitted by Richard A. Suggs in partial fulfillment of the requirements for the Degree of Master of Science from the University of North Dakota, has been read by the Faculty Advisory Committee under whom the work has been done and is hereby approved.

Philip J. Gerla

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This thesis meets the standards for appearance, conforms to the style and format requirements of the Graduate School of the University of North Dakota, and is hereby approved.

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ABSTRACT

During the last three decades, there has been much research on ground water / surface water interaction and hyporheic zone processes in natural rivers and streams. Research into natural systems has revealed significant ground water / surface water interaction and a complex variability that depends primarily on surface conditions, subsurface composition, and seasonal influences. Hyporheic zone interaction is an important factor contributing to water quality of both surface water and ground water systems.

This research expands on the concept of using heat transport, as revealed by temperature variation, as an analogue for water movement within a surface water / ground water system to include the man-made drainage ditch environment. The goal of this research is to use vertical temperature profiles as a means to identify locations along the drainage ditch where surface water / ground water exchange takes place within the hyporheic zone. To achieve this, an array of temperature data loggers was installed in a reach of Judicial Ditch #66 (JD66), within The Nature Conservancy's Glacial Ridge Project, a large-scale prairie / wetland restoration, approximately 24 km (15 miles) east of Crookston, Minnesota.

To characterize the hyporheic zone along the ditch, statistical analyses were conducted on the temperature data collected during the study. The two statistical tests used include a one-way analysis of variance (ANOVA) and a Tukey's test. The trajectory of ground water / surface water interaction, in-flow or out-flow of water from the

channel, can be determined by comparing the results from a set of these statistical analyses. The resulting groups generated by Tukey's tests were reviewed for anomalous results. Locations that fall within an anomalous group suggest the occurrence of surface water - ground water exchange at that point along the ditch. By reviewing the characteristics of the anomaly, the direction of water exchange across the hyporheic zone can be inferred.

The methodology developed during this project may best be applied to processing large data sets generated from data logger instrumentation. The resulting analyses indicate the directionality of hyporheic exchange, if it is occurring at an instrumented location. Because of its ease and low cost, the methodology developed might best be used as a reconnaissance tool to identify areas along a ditch or stream reach for further instrumentation and research.

CHAPTER I

INTRODUCTION

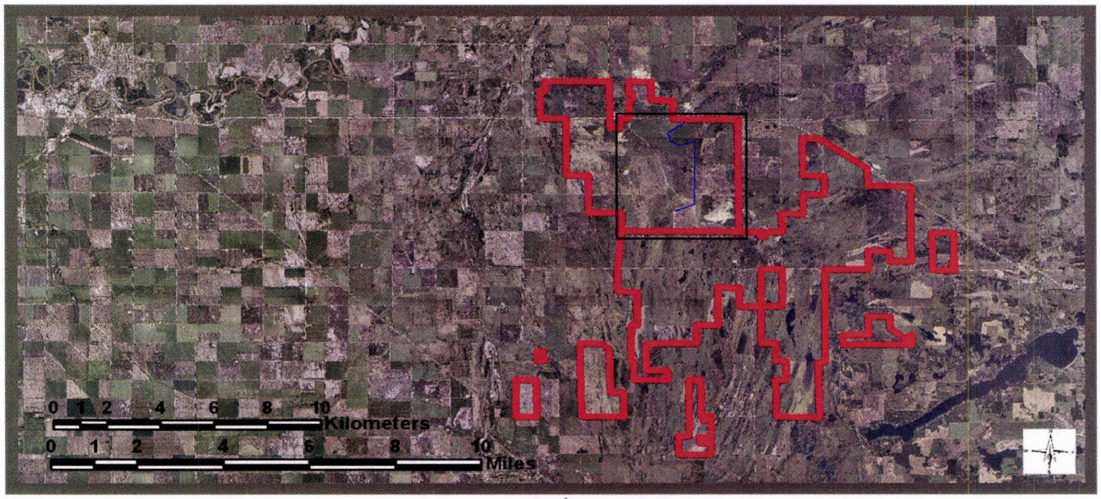
Over the last three decades, there has been much research on the surface water and ground water interface and hyporheic zone processes in natural systems (Woessner 2000). Research into natural systems has revealed significant ground water / surface water interaction and a complex variability depending on, but not limited to, surface conditions, subsurface composition, and seasonal influences (Anderson 2005). The hyporheic zone is an active ecotone between the surface stream and ground water. Exchanges of water, nutrients, and organic matter occur in response to variations in discharge, bed topography, and porosity (Boulton et al. 1998). Hyporheic zone interaction is an important factor contributing to water quality of both surface water and ground water systems.

The intent of this study is to expand the growing body of knowledge regarding hyporheic interaction to include man-made drainages. This will be done by focusing on an agricultural drainage ditch, Judicial Ditch #66 (JD66), located on the Glacial Ridge National Wildlife Refuge in northwest Minnesota (Figure 1). A better understanding of the hyporheic zone interactions observed at JD66 will help determine best practices for ditch management in the region and provide a way to assess the effect of ditch reconfiguration on aquatic ecology at Glacial Ridge.

Officially established in October 2004, Glacial Ridge National Wildlife Refuge encompasses 14,468 hectares (35,750 acres) of the Lake Agassiz beach ridge environment within northwestern Minnesota. The shallow water table and wetlands of the region hinder cultivation; therefore much of the area's natural landscape was altered by an extensive network of drainage ditches, the construction of which peaked during the 1940s and 1950s (Miller and Frink 1984). The Nature Conservancy (TNC) is now completing reconstruction of the hydrologic processes and ecosystems of approximately 4856 hectares (12,000 acres) of wetlands and 5665 hectares (14,000 acres) of tall grass prairie. Most of the area has been turned over to the U.S. Fish and Wildlife Service for inclusion in the Glacial Ridge National Wildlife Refuge.

JD66 is located in Township 149 North, Range 44 West (Tilden Township) in Red Lake County, approximately 24 kilometers (15 miles) east of Crookston, Minnesota. The ditch has a natural drainage area of 36 square kilometers (14 square miles) and an average flow rate of 0.0054 cubic meters per second (0.19 cubic feet per second). Most of the flow through the ditch originates from a gravel pit, which will likely operate for a few more decades (The Nature Conservancy 2009). The water is colder and more mineralized than water elsewhere at Glacial Ridge. The flow rate is constant throughout much of the year and has significantly increased the volume of water entering the watershed since the pit was developed in the 1980s (Brown et al. 2005).

In an effort to account for increased water flow related to the existing gravel pit, TNC's plan for restoring the JD66 drainage area included retrofitting the ditch with a flood plain and small channel. At the time of this study, that work had not yet been started, but it was completed in 2009. It was determined that a characterization of



a.)

b.)

Figure 1. a.) 2005 National Agriculture Imagery Program (NAIP) aerial image of study area. The Glacial Ridge National Wildlife Refuge is outlined in red and the black outline shows the study area, JD66 identified by a blue trace. b.) Close-up image of area outlined in black.

hyporheic zone interaction before the retrofit could be of use in assessing the success of the restoration. Unfortunately, shortly after restoration efforts at JD66 were completed, pit dewatering increased to 0.057 cubic meters per second (2 cubic feet per second) from the pit. The change has altered the flow of JD66, and will make evaluation of restoration efforts at the ditch difficult for the immediate future.

Goals

This research expands the concept of using heat transport as an analogue for water movement within a surface water/ground water system to include the man made drainage ditch environment. The ultimate goal of this research is to use temperature gradient as an indicator of locations along the drainage ditch where surface water/ground water exchange takes place across the hyporheic zone, and to do so cost effectively and continuously over a long time period. To achieve the stated goals, it was necessary to identify and evaluate a temperature data logging device, develop a technique to introduce the logging device into the system, and to develop a methodology to interpret the data collected.

Overview

Initially, temperature data were collected with the intent of developing a numerical model that could characterize the trajectory and possibly the rate of surface water/ground water exchange in the ditch system. The model was to use the temperature data as an analogue to track water movement through the hyporheic zone along JD66. Due to the lack of ancillary data, such as hydraulic head data, it was determined that a numerical model developed using the collected temperature data would not adequately characterize hyporheic zone interaction. Therefore, rather than developing a numerical model, a statistical analysis of the temperature data was performed to characterize the hyporheic zone.

The trajectory of the ground water/surface water interaction, in-flow or out-flow of water, can be determined by comparing the results from a set of statistical analyses using two statistical tests. First, a one-way analysis of variance (ANOVA) test was used to determine whether or not the data collected represented more then one statistically significant group. The ANOVA test was then followed by Tukey's test to identify those statistical groupings. The results from theses two tests were then used to identify a location of interest where a surface water/ground water exchange of some type is likely occurring.

Literature Review

There are two areas of research that are pertinent to this particular study. The first includes research conducted to better understand the hyporheic zone. This work is dedicated to understanding the active ecotone between the surface water and ground water, where exchanges of water, nutrients, and organic matter occur in response to variations in discharge and bed topography and porosity (Boulton et al. 1998). The second area of research important to this study includes work that uses heat as a tracer of ground water movement (Anderson 2005). Obviously, the research of greatest importance to this study would focus on a combination of both areas, specifically, attempts to characterize hyporheic processes by using temperature measurements.

Anderson (2005) thoroughly reviewed research involving the use of heat as a ground water tracer. The review indicated that interest in using heat as a ground water tracer peaked in the 1960s and again in the late 1980s. Anderson described earlier works that suggested and/or attempted to use heat as a tracer in the ground water system, and pointed out that there has been a significant increase in activity in the subject due to the recent availability of affordable and accurate temperature sensors.

Fernald and Guldan (2006) were interested in irrigation ditch seepage effects on surface water/ground water interaction. They placed three transects of slotted PVC wells between the Alcide Ditch and the Rio Grande River in New Mexico. Water levels were measured weekly over two years. Measurements revealed seasonal patterns of shallow ground water flow and showed that the shallow ground water table in the area responded to seepage from the irrigation ditch within one to two weeks of a ditch flow. This caused a raised water table and orientated flow paths towards the river. Specific conductance of the water increased in wells when the ditch flow was off and decreased when the ditch was flowing, indicating the ditch seepage impact on the shallow ground water.

Bukaveckas (2007) studied stream sites in Kentucky and Indiana that were previously channelized and then returned to a naturalized state. Bukaveckas (2007) was interested in the effects the restoration would have on water velocity, transient storage and nutrient uptake. It was discovered that water temperature was higher and velocity was lower in the restored channel versus the channelized condition. Both transient storage and nutrient uptake were higher in the restored channel. Bukaveckas (2007) concluded that stream restoration is a useful strategy to mitigate downstream nutrient transport.

Bravo et al. (2002) compared four different models that used coupled heat and ground water flow modeling and also allowed estimation of boundary fluxes and hydraulic conductivity. The flow and heat models included were a 1-D steady flow and transient heat transport synthetic model, a 3-D steady state synthetic model with noise-free observations, a 3-D steady state synthetic model with noisy observations and finally a steady flow and transient heat transport model. All the models were run with data collected from a wetland field site near Wilton, Wisconsin. They concluded that the joint inversion of head and temperature data is an effective method to estimate simultaneously the hydraulic conductivity and in-flow to wetland systems. Also, synthetic and field models did not converge when only head data were used, but did converge when head and temperature data were combined.

Conant (2004) conducted a detailed streambed temperature mapping study on a 60-meter stretch of the Pine River in Ontario, Canada. Conant (2004) focused on developing a flux model using the relationship of streambed temperatures and flux estimates made at piezometer locations. Using this model, Conant (2004) identified and mapped five basic types of discharge occurring in the stream reach. Type 1 discharge behavior, or short circuit discharge zones, are localized points of high discharge such as artesian springs. Type 2 is high discharge zones, areas of preferred ground water flow where high hydraulic conductivity deposits in the streambed connect the underlying hydraulic conductivity aquifer deposits directly to the river. Type 3 is a low to moderate discharge zone caused by low to medium hydraulic conductivity deposits. Type 4 is a no-discharge zone where the vertical hydraulic gradient between the streambed and river is zero. Type 5 is a recharge zone where hydraulic gradients between the river and the streambed are downward. It is likely that several of the five types of discharge identified by Conant (2004) exist within the reach of JD66 studied in this work.

Malard et al. (2001) studied thermal heterogeneity in the hyporheic zone at several sites within the glacial floodplain of the Roseg River in the Swiss Alps. Temperature and silica concentrations of the water were collected. Silica concentrations were shown to be higher in ground water than in the surface water within this floodplain. Using the statistical test ANOVA and Tukey's multiple comparison test, they evaluated the differences in silica concentrations and temperature patterns. The results indicated the vertical pattern of water temperature was strongly influenced by the direction and intensity of water mixing in the hyporheic zone. Also, inflow of shallow ground water had minimal effects on seasonal hyporheic temperature, but deep ground water resulted in significant differences.

Silliman et al. (1995) presented a simple mathematical model to quantify flux across the sediment, assuming constant flux and one-dimensional downward flow. They based their study on the argument that temperature in sediments will be controlled by advection of thermal energy through fluid flow and conduction of thermal energy. The authors discussed three extreme flow cases including: a strongly gaining stream where sediment temperature will be controlled by advection from ground water, a zero flux stream where conduction prevails, and finally, downward flow from the creek to the subsurface, where both advection and conduction play a part. This final case is the focus of the paper. With a properly designed experiment and the benefit of known thermal and physical properties of the sediments, this procedure can be useful in field situations to estimate flux in a stream site.

Most of the papers summarized above focus either on identifying and quantifying hyporheic exchange by using water temperature, or on identifying site-specific hyporheic zone characteristics or processes in a variety of environments. Research dedicated to using temperature to identify and/or quantify hyporheic exchange typically develops a site-specific calibrated model or set of equations that fits observations. Most of these studies require relatively costly instrumentation or that data be collected at discrete times.

One goal of the present study is to develop a cost-effective method to instrument streams and ditch channels for studying hyporheic zone interaction. Another goal is to continuously monitor a large reach to identify zones of more complex and variable hyporheic processes. Of the papers that focus on identifying hyporheic characteristics or processes, most research has focused on natural drainages such as rivers and streams, and how the hyporheic zone is important to those waters. Those works that used temperature change or heat as a variable typically used measurements taken at one or two discrete time periods. In contrast, few studies have focused on the effects of hyporheic exchange in non-natural headwater channels, or evaluated temperature measurements taken continuously over a seasonal time frame.

CHAPTER II

METHODS

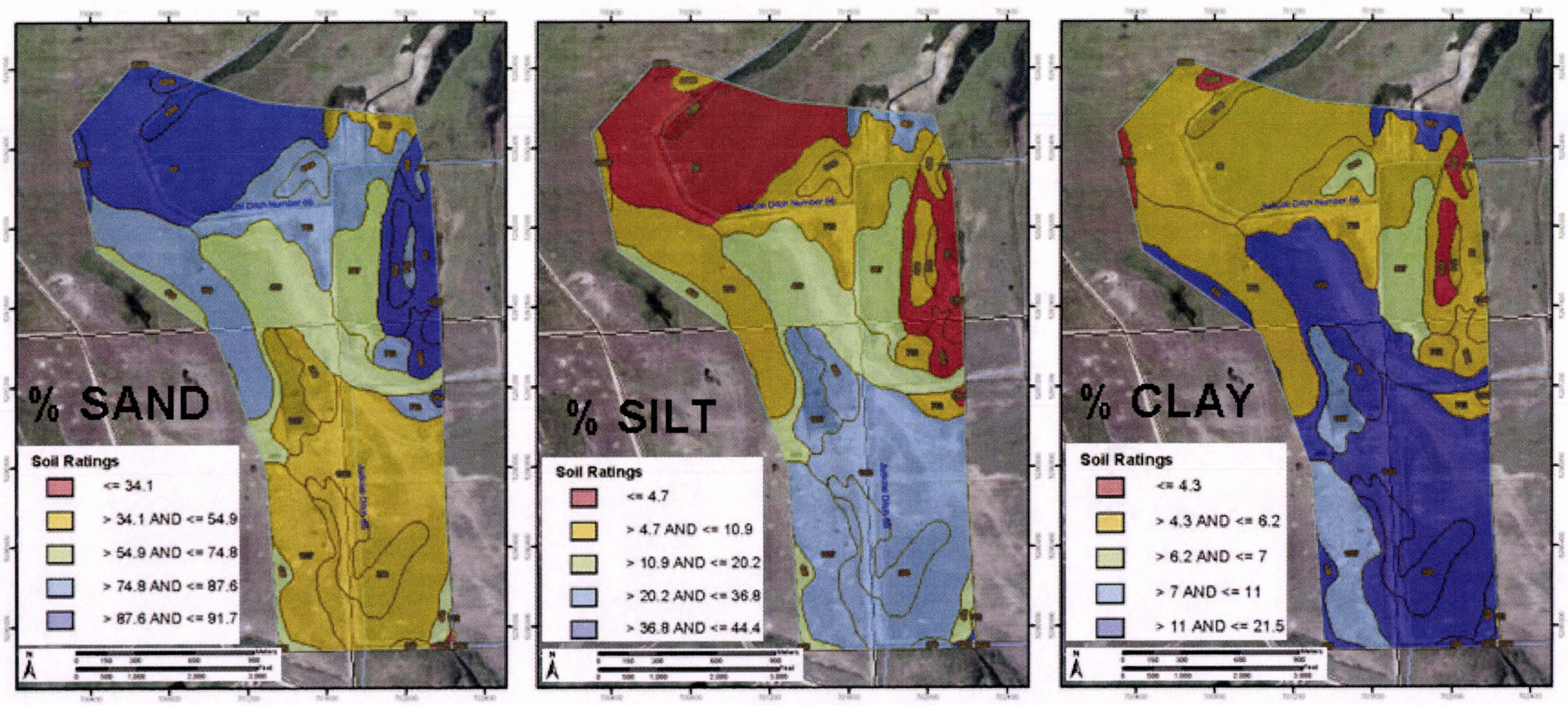
The 2.4 kilometer (1.5 mile) reach of JD66 monitored during this project was chosen as the study location for two reasons. First, JD66 was scheduled for reconstruction as part of The Nature Conservancy's plan for restoration of the Glacial Ridge area. The attempt to characterize hyporheic interaction across the ditch, if successful, would be useful for determining the overall effectiveness of the final restored environment. The second reason for choosing JD66 was because of the nearly constant flow that exists in the ditch, which is fed by drainage from the gravel pit that lies immediately south of the study area. Characterization of hyporheic exchange in a ditch that flows intermittently, which is typically the case in the region, is more difficult and time consuming.

Geology and Soils

The area encompassed by the Glacial Ridge National Wildlife Refuge is part of a beach ridge environment that was shaped by the shores of glacial Lake Agassiz. The surface geology and topography of the study area were shaped first by glacial activity during the Wisconsin glaciation, and followed by the filling and draining of Lake Agassiz as the glaciers retreated (Teller and Clayton 1983). Typical of a beach ridge environment, the soil type is highly variable, ranging from coarse gravel and sand on the ridges to glacial till and/or clay between ridges (Figure 2).

Figure 2. 2005 NAIP aerial image showing Lake Agassiz beach ridge topography highlighted by yellow dashed lines. Densely spaced North-Northwest trending beach ridge topography south of the study area is outlined in a red oval. JD66 is identified by a blue trace.

Figure 3. Preliminary soil study. a.) Installation of a boring. b.) Example of gleyed soil. c.) Organic-rich soil found at the surface of each sample location. d.) Sample of clay from southern part of the study area. e.) Sample of clayey sand from the center of the study area. f.) Sample of coarse gravelly sand from the northern portion of the study.



a. b. c.

Figure 4. Natural Resources Conversation Service (NRCS)'s Web Soil Survey, soil composition maps over the study area. a.) % Sand Map. b.) % Silt Map. c.) % Clay Map

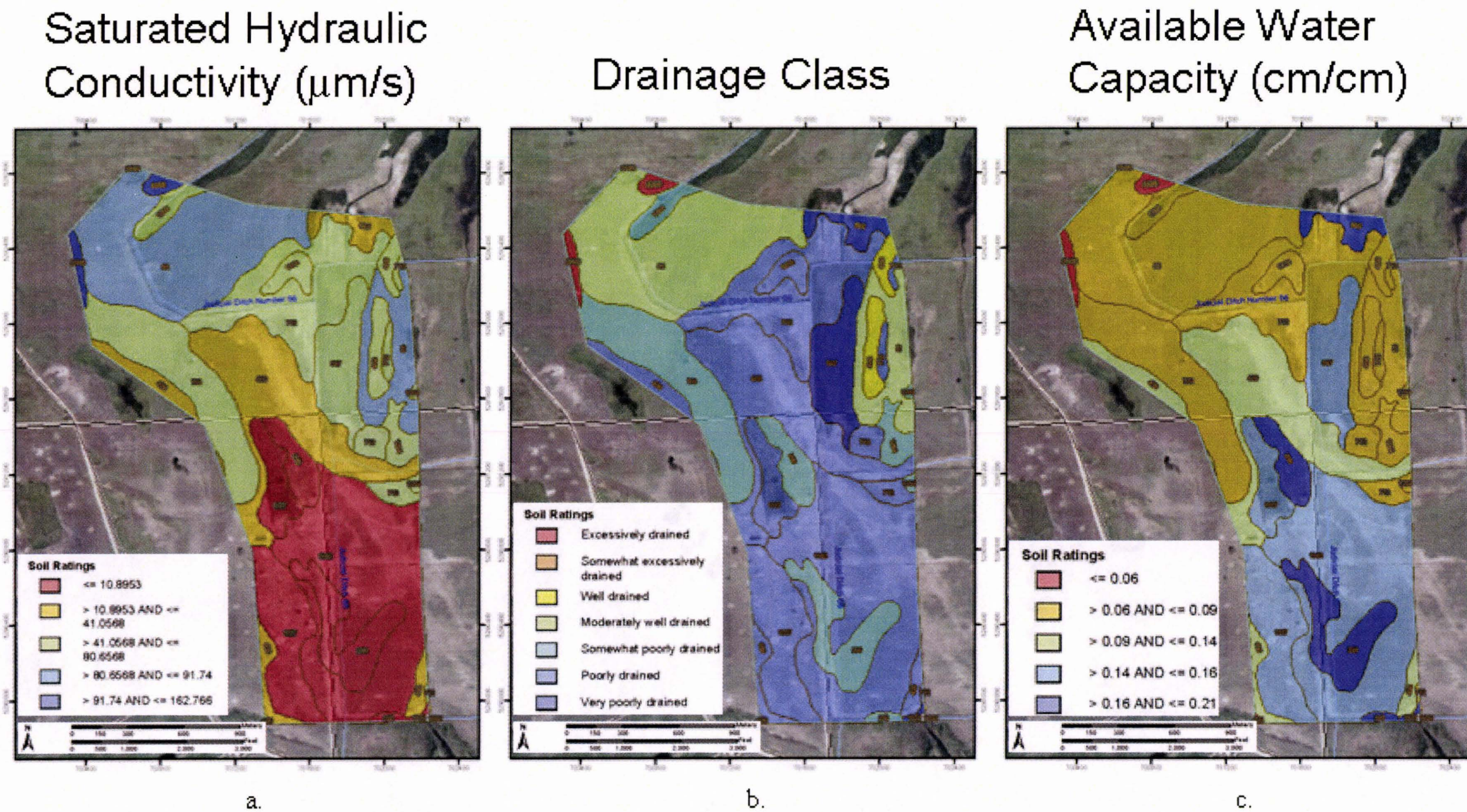


Figure 5. Natural Resources Conversation Service (NRCS)'s Web Soil Survey, soil property maps over the study area. a.) Saturated Hydraulic Conductivity Map. b.) Drainage Class Map. c.) Available Water Capacity Map

Selection of Monitoring Sites

The 12 sampling locations along the reach (Figure 6) were chosen by observing flow characteristics, water depth, and vegetation along the ditch. Loggers were located across areas exhibiting a variety of flow characteristics such as those found in wider shallower stretches and those in narrower deeper stretches. The loggers were separated

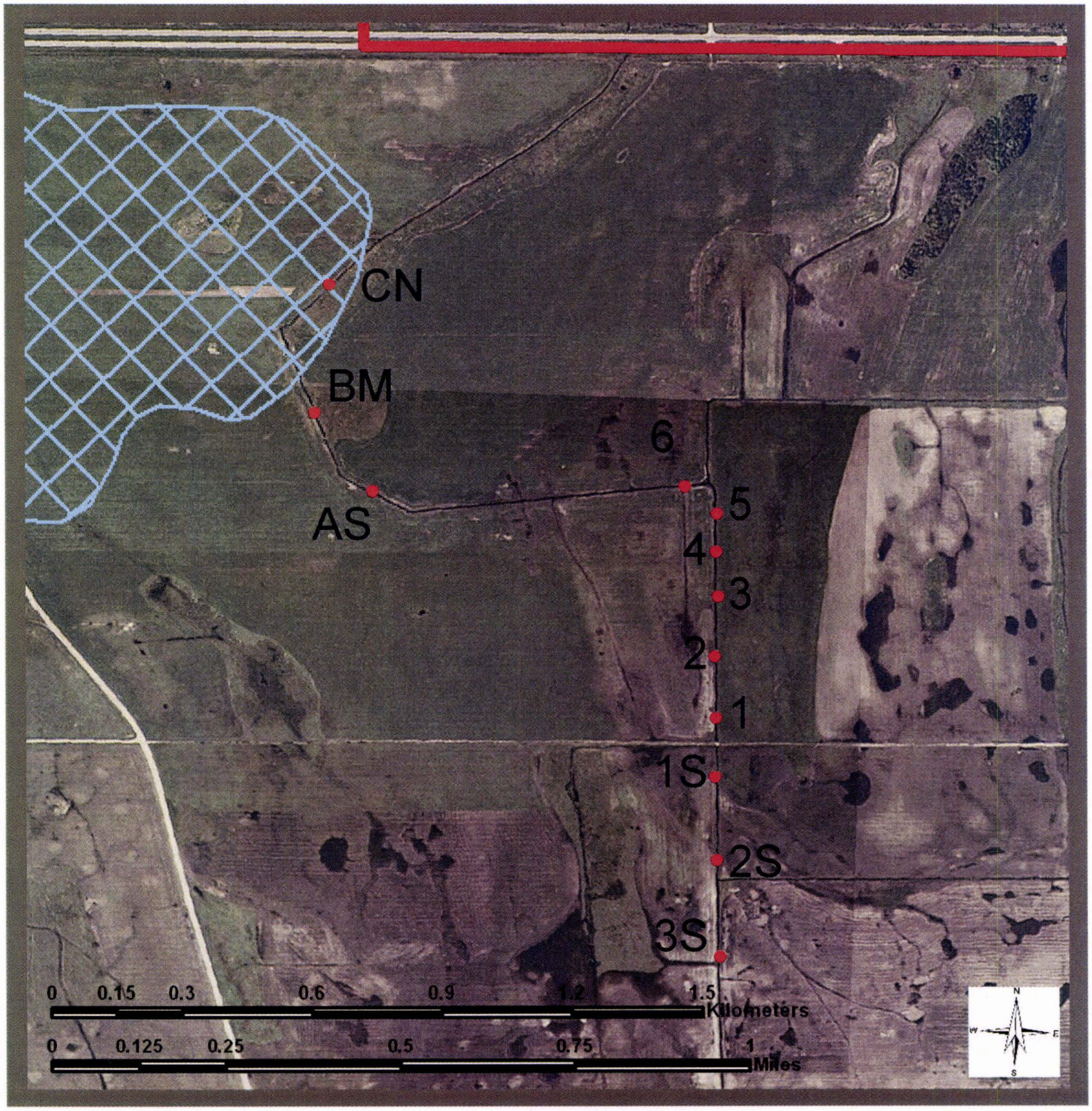


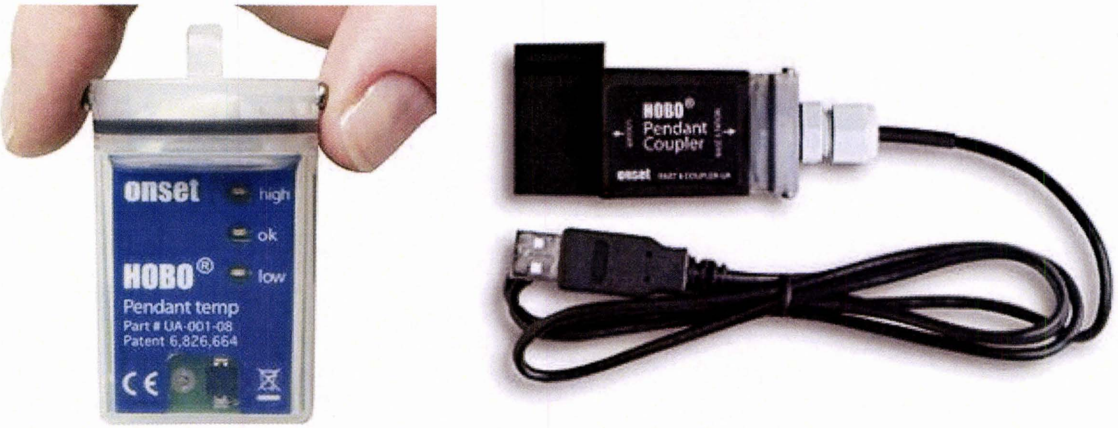
Figure 6. Location of installed loggers identified by a red dot, Crookston wellhead protection area identified by a blue crosshatch.

by an approximately equal distance, and located in areas with sufficiently deep water to prevent a low water level from exposing a logger to air. Heavily vegetated areas were avoided to minimize effects of shading and also allow for easier logger deployment and retrieval purposes.

Logger Specifications

Temperature data for this project were collected using the Onset HOBO Pendant temperature data loggers, model number UA-001-08. The data loggers have a measurement range of -20 to 70 degrees Celsius (-4 to 158 degrees Fahrenheit), ± 0.47 degrees Celsius (0.85 degrees Fahrenheit) accuracy, and an approximate five minute response time in water. It was determined the HOBO logger would be sufficient for purposes of this study, as conditions in the ditch during the study period were not expected to exceed the logger's range, and that temperature change in the ditch would be gradual enough that the logger response time would not be a problem. The HOBOware Pro software and a Pendant Base Station and Coupler device provided logger-to-computer communication for logger launch and readout of the HOBO Pendant loggers. The Base Station Coupler device attached to the computer via USB ports and allowed for optical infrared (IR) communication with the individual loggers (Figure 7).

In an effort to maintain uniform sampling conditions at each measurement location, it was necessary to design a housing that would not only protect and hold the



a.) b.)

Figure 7. a.) Image of HOBO logger. b.) Image of Pendant Base Station and Coupler device (images from www.onsetcomp.com).

HOBO loggers, but would also allow for easy deployment in the field and extraction of the logger data. Two different housings were designed.

The first design consisted of a variable length of 3.175 centimeters (1.25 inch) diameter, schedule 40 PVC pipe with an auger attached to one end. The housing was designed to be installed using a slightly larger metal outer casing, which could be slipped over the PVC portion and used to apply torque directly to the auger end of the housing, and removed after installation. The loggers were attached to a length of fishing line at the desired sampling interval, small weights were attached to the bottom of the line and the upper part of the line was attached to the housing cap. The string of loggers hung inside the PVC pipe, essentially separating the pipe into individual compartments. The pipe was then filled with water or propylene glycol antifreeze (depending on expected sampling conditions) (Figure 8).

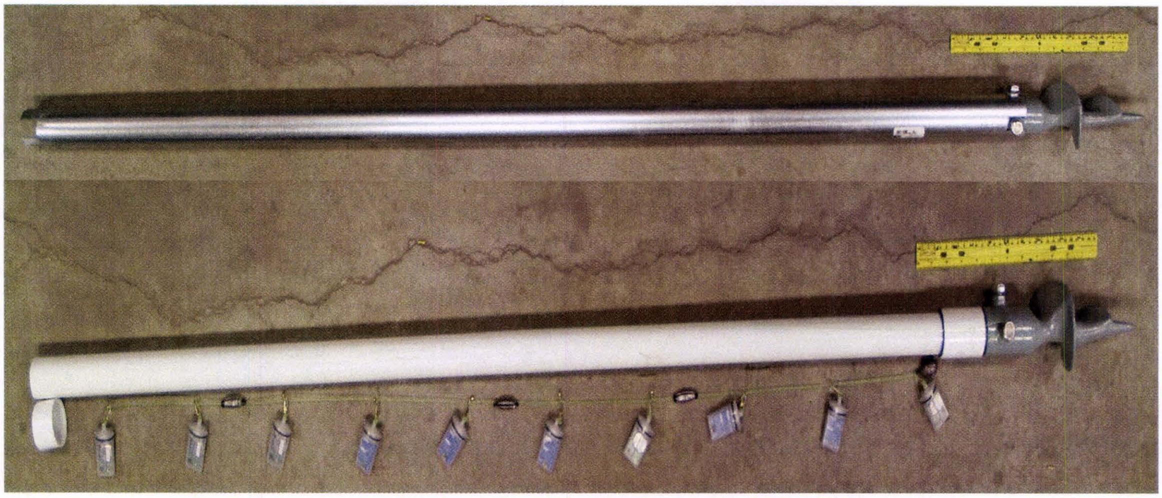


Figure 8: Picture of Housing Design #1

This housing design attempts to minimize both heat conductance through the outer housing, and convective mixing in the internal fluid, thus allowing for a more representative measurement of in-situ temperature measurements. This housing design allows for relatively deep temperature measurements, flexibility in the vertical spacing between loggers, and surface access to the loggers for easy data retrieval. Another benefit of this design is that it is not limited to use in a stream or ditch setting, but can be used in a variety of environments to measure soil or ground water temperatures.

The second design developed consisted of a housing made from two variable length sections of 3.8 centimeter (1.5 inch) diameter, thin-walled PVC tubing connected by a short piece of 3.175 centimeter (1.25 inch) schedule 40 PVC pipe. The bottom end of the thin-walled PVC was notched in such a way to allow a logger to be inserted into the end and the two halves pinched together to form a point. The short piece of schedule 40 pipe was perforated to allow water to flow through the housing. The second piece of thin-walled PVC, which was long enough to rise above the surface of the water, was attached to the top. Two small plugs of foam were located inside the tube, one above and one below the middle logger, to minimize any vertical convective mixing of water inside the housing. The housing was designed to contain three loggers spaced approximately 20 centimeter (8 inch) apart. Once installed in the ditch, the middle logger located in the schedule 40 section of the housing was placed just into the streambed sediment; the top logger, attached to the exterior of the housing, was within the water column and the bottom logger deeper in the sediment (Figure 9). This design minimized heat conductance through the outer housing, and convective mixing in the internal fluid, while maximizing each loggers contact with in-situ water conditions. This design is lightweight, easy to install, and ideal for deployment in a ditch or shallow stream environment. It would likely not be suitable for deployment in higher energy environments.

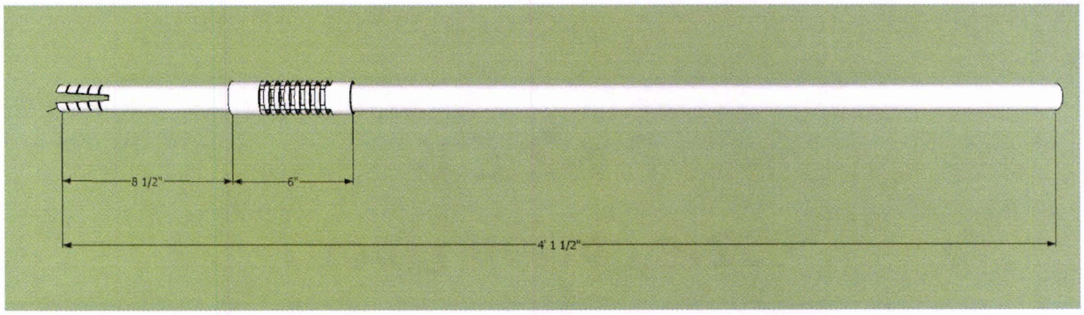


Figure 9: Diagram of Housing Design #2

Field Implementation

In an effort to initially determine how the HOBO logger would perform, a test was run for 69 days from November 4, 2007 to January 11, 2008 (Appendix B). Ten loggers were installed utilizing logger housing design number one as described above, inside the housing each logger was spaced 15 cm (6 inches) apart starting at 30 cm (12 inches) above the ground surface to a depth of 106 cm (42 inches). The location for this initial test run was on the west side of the ditch just south of location one (Figure 4). The test was performed late in the fall, and winter conditions set in prior to extraction of loggers. The loggers remained frozen in place over the winter and the storage capacity of the loggers was exceeded before the loggers were retrieved. The preliminary review of the logger data collected during this test run resulted in several observations, including the unexpected possibility that different soil horizons could be identified by their thermal characteristics as the ground froze. It was also decided that 15 to 30 cm (6 to 12 inch) spacing of the loggers would be sufficient for the greater part of the study, and a three logger housing design, as described above, would be sufficient to characterize the water column at a given location.

For most of the project, loggers were originally installed April 20, 2008, at nine locations over a 1.13 kilometer (0.7 mile) reach of JD66. The extent of the study area was expanded May 18, 2008. Three additional locations on the north were included to monitor the ditch within Crookston's wellhead protection area. These were loggers AS, BM, and CN (Figure 4) Ultimately, twelve housing devices with three loggers each totaling thirty-six loggers were installed along approximately 2.4 kilometer (1.5 mile) reach of JD66. At each measurement location a housing apparatus was inserted into the stream sediments near the center of the stream so that the loggers would be positioned with one logger in the water column, one just into the streambed sediments and the third logger deeper in the sediment.

The individual data loggers were programmed to record a temperature reading once every ten minutes. Three factors went into the decision to use the ten-minute sampling interval. First, at the ten-minute interval the loggers had enough storage capacity to log continuously for approximately 45 days. The loggers could be pulled and data retrieved once a month allowing for an additional two weeks of logging time should any complications delay a scheduled data retrieval trip. Second, it was decided that the ten-minute interval would be more than adequate to observe variation in daily to seasonally temperature cycles. Third, the data generated would allow for the flexibility to reduce the size of the data set by choosing a larger interval and extracting the appropriate subset of data.

Data Processing

The data collected at locations 3 and BM were excluded from the statistical analysis because portions of the data were missing or otherwise unusable. At location 3 one of the three loggers was lost during a collection period. A logger at location BM was programmed incorrectly for a portion of its deployment. Use of the data from either logger would have introduced inconsistency into the overall data set, possibly skewing the final results. For similar reasons it was also decided to exclude the data collected prior to May 18, 2008, when only 9 of 12 locations were installed.

Only the raw data collected were analyzed using the statistical methods described below. The temperature data could have been normalized or preprocessed in a number of ways to account for variability or drift between logging devices, but the decision to use the raw data was made for several reasons. One such reason is that preprocessing or manipulating the data ultimately requires changing the data in some way, and it is this author's opinion that manipulation of the input data might lead to uncertainty regarding the true meaning of the resulting analysis. Another reason for using only the raw data in the analysis is to preserve as much of the natural variability recorded as possible. Unfortunately any manipulation of the data would likely not only remove variability introduced by the individual loggers but would also remove some of the systems natural variability. Ultimately, the decision to work with the raw data was made partly because the data had been collected prior to running any logger specific diagnostic tests that could have been run before deploying the loggers. It would have been appropriate to simultaneously test each of the loggers under strictly controlled temperature conditions over an extended period of time, possibly several days to a week. Such a test would provide calibration data for each of the individual loggers and may have identified the existence or extent of any logger drift issues associated with the individual loggers. As such a calibration test was not done prior to deployment of the loggers it was decided that attempting to correct for a potential error that had not been empirically identified would have been inappropriate.

Statistical Analysis

One-way analysis of variance (ANOVA) is a technique used to compare samples in two or more groups. The null hypothesis for one-way ANOVA is that the samples in two or more groups are derived from the same population (Hill and Lewicki 2007). For this study, the groups consist of logging locations and the dependent variable is temperature. Two assumptions relevant to the distribution of the data that are important to the ANOVA test are that the data be normally distributed and that the data have equal variance. The ANOVA test itself is generally robust against violating these assumptions (Zar 1996), specifically with respect to testing where sample sizes between groups are equal and sufficiently large, which is true for the analyses presented in this work.

Provided that the ANOVA test returns a significant result, the ANOVA test can be followed by Tukey's test to determine which groups are significantly different from one another. Assumptions of the Tukey's test include that observations are independent, the means are normally distributed, and observations have equal variance (Zar 1996).

In this study, the groups compared using ANOVA consisted of the temperature data collected at each of the three distinct horizons. The first group is temperature data collected in the water column (G1). The second group is the temperature data collected at the surface water / ground water interface (G2). The third group is the temperature data collected in the streambed sediments (G3). Using ANOVA followed by Tukey's test, temperatures in G1 and G2 were compared to determine at which locations the temperatures in the two horizons were determined to be statistically different. G2 and G3 temperatures were compared likewise. The results from the first analysis, G1 versus G2 and the second analysis G2 versus G3 were then compared to each other in an effort to determine directionality of water movement. Ideally, a losing portion of the ditch or a location dominated by ground water recharge might have loggers from G1 and G2 identified as statistically similar, and a gaining portion of the ditch, ground water discharge, might have loggers from G2 and G3 identified as statistically similar.

The process described above was used to evaluate three different portions of the entire data set. The analysis was initially performed over the entire data set from May 18, 2008 through November 1, 2008 (Analysis A - Full Data). After a visual inspection of a plot of the entire data set, it was decided to run the analysis over two other shorter time periods: June 19, 2008 through August 20, 2008 (Analysis B - Summer Data), and September 1, 2008 through November 1, 2008 (Analysis C - Fall Data). The actual statistical analysis was performed using "R" Stats, a free statistical, computing, and graphics software package distributed by The R Project for Statistical Computing (Hornik 2010). Many of the resulting graphs and data presented below are generated through the use of "R".

While the entire results of the ANOVA and Tukey's tests as reported by "R" are included in Appendix C, the results from the above described statistical tests are presented in the results section below in a standard format as follows for the ANOVA analyses F (d1,d2) = fval (P). Where F indicates the reporting of the value of the F ratio as calculated during the ANOVA test. The d1, and d2 values represent the two different degrees of freedom values associated with the F-test as it is calculated in the ANOVA. The d1 value represents the between subject variance which is the number of subjects minus one, in this case each analysis involved the comparison of twenty subjects (loggers) so d1 will equal twenty minus one or nineteen. The d2 value represents the within observations variance which is the number of observations minus the number of subjects (loggers) this value will vary in the following results. The fval is the value of the F ratio as calculated during the ANOVA test. The significance of the test results is denoted by a probability value or p-value (P), the closer the p-value is to zero the more significant the results. For the Tukey's test a "p" value as reported by "R" greater than 0.05 indicates that the means of a particular logger pair are statistically similar to 95% or greater. In the following section the results from the Tukey's test are reported graphically in groups of statistically similar loggers rather than as listing the results of each comparison. As indicated above, the full report as generated by "R" is available in (Appendix C)

CHAPTER III

RESULTS

The results generated from the three time periods described above as Analysis A - Full Data Set, Analysis B - Summer Data, and Analysis C - Fall Data will be addressed individually in the following discussion. The extent to which each analysis meets the assumptions required for the statistical method will be included in each section, along with conclusions specific to each period. The description of analysis A will be more detailed as to the actual process, with the descriptions of analysis B and C being a summary of the statistical results followed by the individual case observations and conclusions. Before reviewing specific results or observations from the individual analyses, some of the results common to all three analyses are included in the following paragraph.

As expected when reviewing a G1 to G2 analysis (top loggers to middle loggers) individual loggers from G1 tended to group with other loggers from G1, and loggers from G2 tended to group with other loggers from G2. Similar results were obtained from an analysis of G2 to G3 (middle loggers to bottom loggers), loggers from G2 tended to group with loggers other loggers from G2 and loggers from G3 tended to group with loggers from G3. When data from loggers at a particular horizon are compared, an anomalous result (a logger groping with loggers from a different group or horizon) from one or more loggers suggest unique hyporheic interaction of some type is likely occurring at that location. Such an anomalous condition identifies an area where increased instrumentation may yield more definitive conclusions as to the nature of the hyporheic exchange.

Another result common to each of the analyses described below is that each of the ANOVA tests identified high probabilities that the data analyzed consisted of two or more statistically significant populations. This result is expected because data from two different horizons in the water column are included in each analysis. In a simple system with no hyporheic exchange, an ANOVA test done on a data set that included data from two distinct horizons would identify a high probability that two or more distinct populations existed, and Tukey's test would separate data into the two groups, one for each horizon. The groupings yielded by the actual analyses indicated a more complex hyporheic exchange system, with each of the individual analyses identifying several statistically significant groups. As mentioned above, locations of interest are identified by the different logger groupings identified in each analysis.

Analysis A (Full Data)

As indicated above, the analysis of the data collected May 18, 2008 through November 1, 2008 (Figure 10), was done in two parts. The first part of the analysis compared the data from G2 and G3. In each analysis a histogram and box plot of the data collected over the interval were visually evaluated to determine if the data satisfied the assumptions required to be true for the ANOVA and Tukey's tests (normal distribution and equal variance). The resulting histogram showed a slightly skewed normal

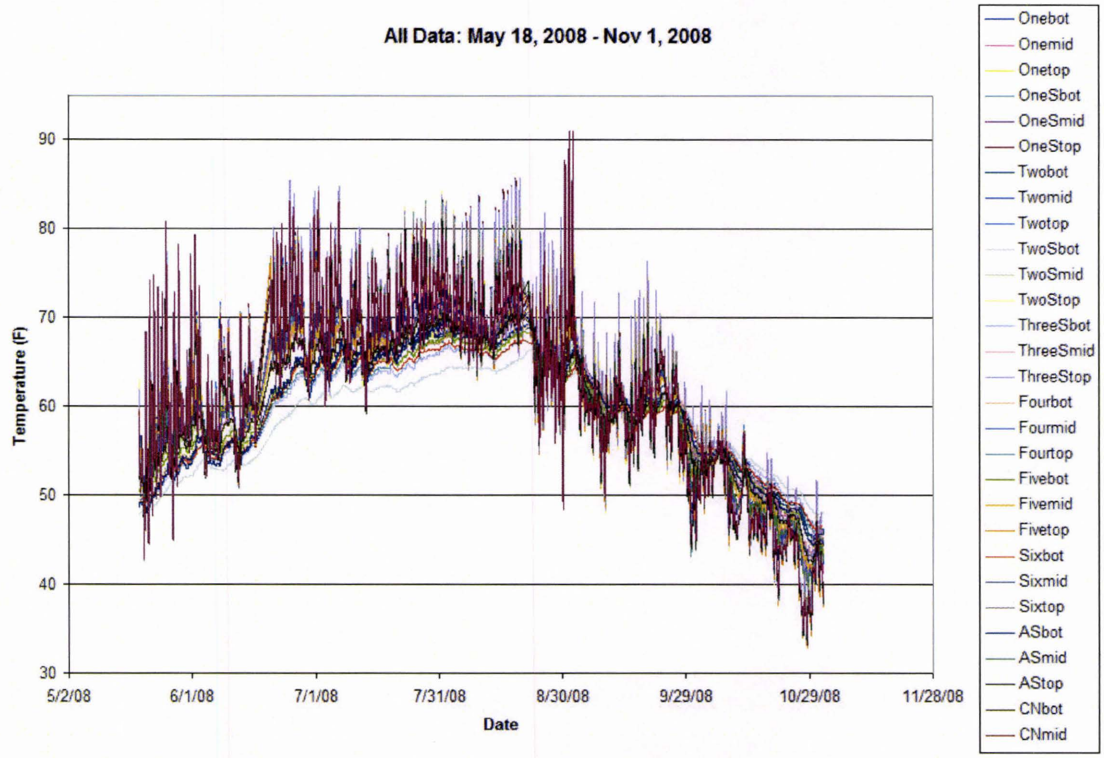
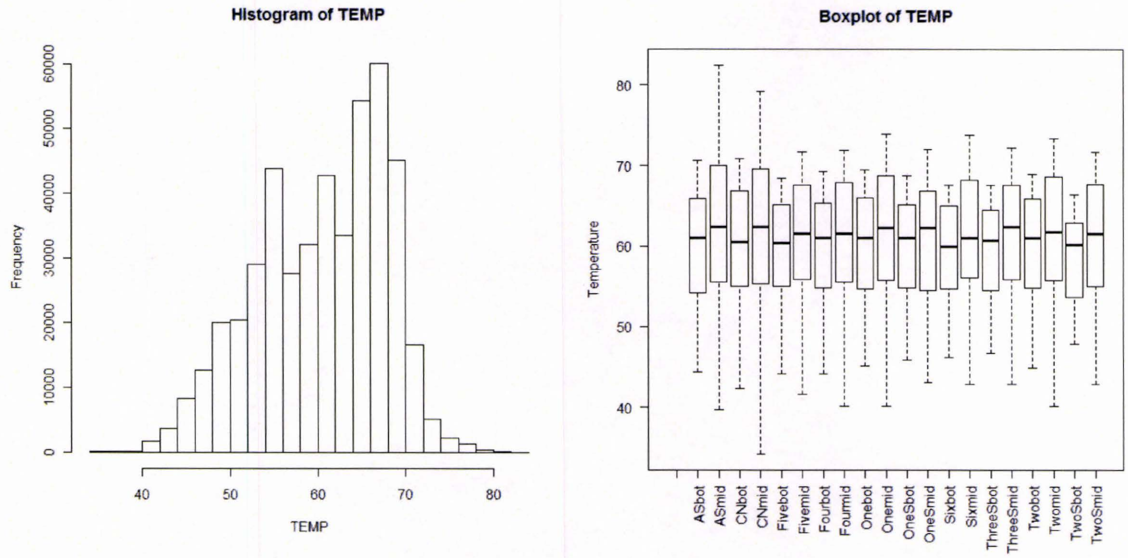


Figure 10: Plot of data used in analysis A (Appendix D)

distribution and the box plot indicated remarkably equal variance (Figure 11). The resulting ANOVA analysis yielded F (19, 462400) = 337.13 (2.2 e-16).

The ANOVA result indicates that in the G2-G3 comparison there were two or more statistically significant populations, significant at 95% and to 99%. With the significant result from the ANOVA test, Tukey's test was run to separate the loggers into distinctly different groups. The significant pairings were then evaluated and groups are formed on the basis of statistically similar logger pairs (Figure 12). In figure ten and the similar figures that follow each logger involved in the analysis is listed and depicted in no particular order, and each has been assigned to one or more groups. Those groups are denoted both by a letter and a color, for example in Figure 10, logger Onebot has been included in two group noted along the bottom as groups A and C, the mean temperature



a.) b.)

Figure 11. Analysis A, G2 – G3 portion. a.) Histogram. b.) Boxplot.

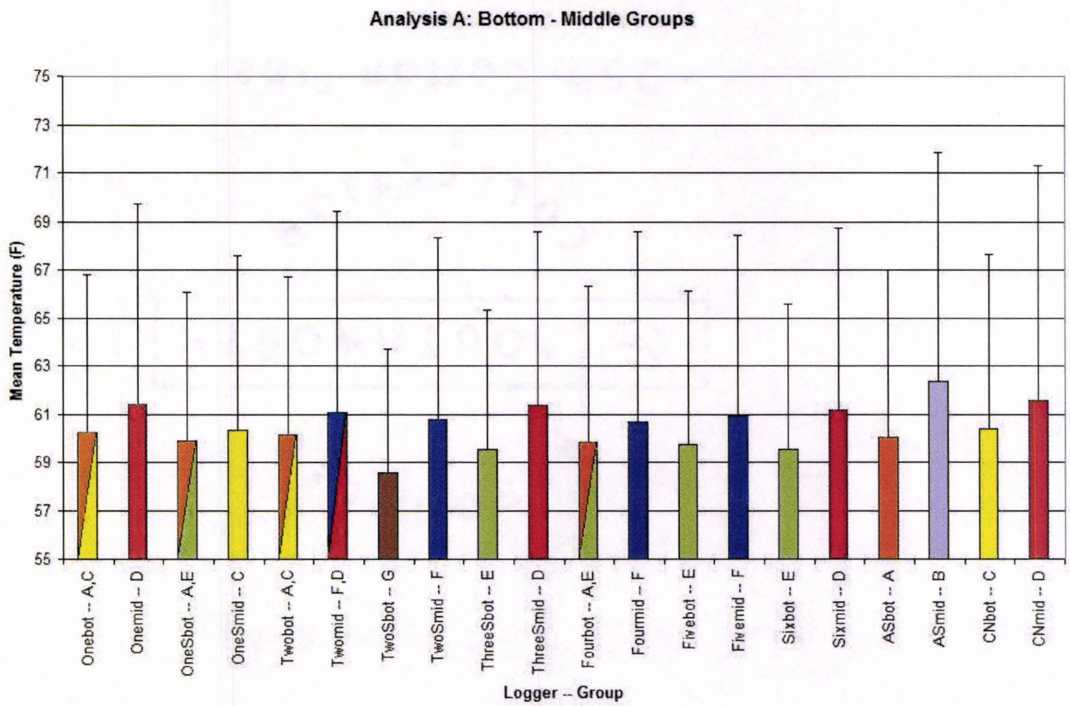


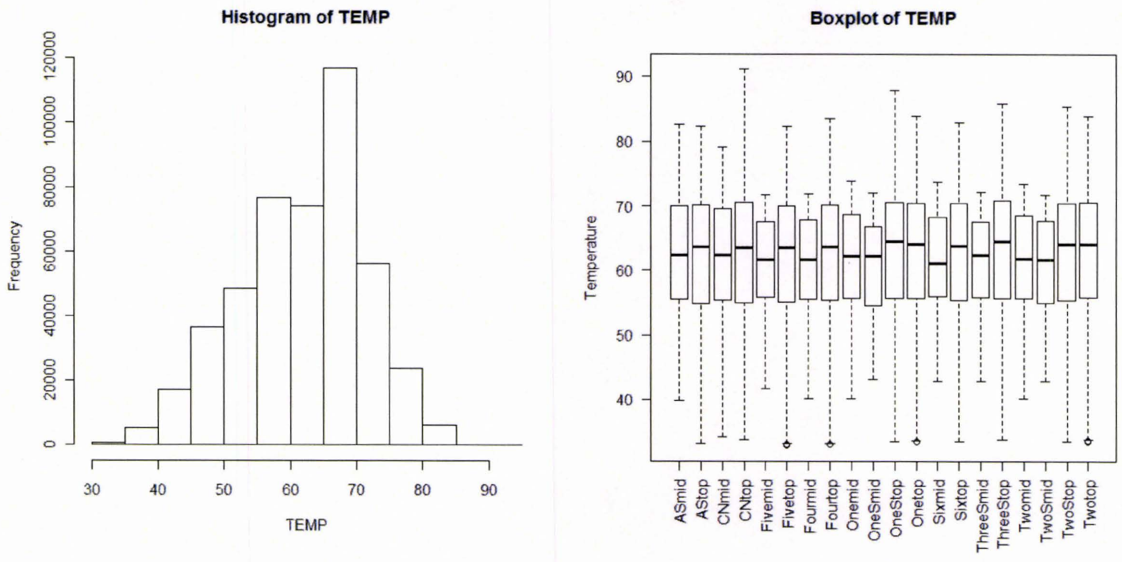
Figure 12. Analysis A, G2 – G3 portion, showing standard deviation and mean temperatures of each logger, logger groups are color-coded.

bar has also been divided into two colors to aid in a visual interpretation of results, in this case orange for group A and yellow for group C.

The second part of the analysis compared G1 and G2 data. Again, a histogram and a box plot of the data were visually evaluated to determine normal distribution and equality of variance. In this case the visual inspection of the histogram indicated a relatively normal distribution of data, and again the box plot revealed a remarkably equal variance in the data (Figure 13). The ANOVA results were as follows: $F(19,462400) = 205.39$ (2.2e-16). The resulting G1-G2 comparison again indicated two or more statistically significant populations, significant at 95% and to 99%. Following the significant ANOVA result, Tukey's test was run to determine statistically similar logger pairs and groupings determined (Figure 14).

As indicated above, loggers from each of the three horizons were expected to group together, as is the case with the majority of the data. An unexpected observation was that there was more than one distinct grouping of each logger horizon. For example, in the G1-G2 portion of the analysis there were two different groups composed solely of middle loggers and two different groups composed almost exclusively of top loggers. This indicates that to some extent there are potentially different zones of ground water to surface water interaction across different reaches of the ditch.

Specific locations of interest noted in the comparison between the G1-G2 analysis and the G2-G3 analysis include the AS location and the OneS location. The AS location appears to be yielding the type of results initially anticipated in that a middle logger



a.) b.)

Figure 13. Analysis A, G1 – G2 portion. a.) Histogram. b.) Boxplot.

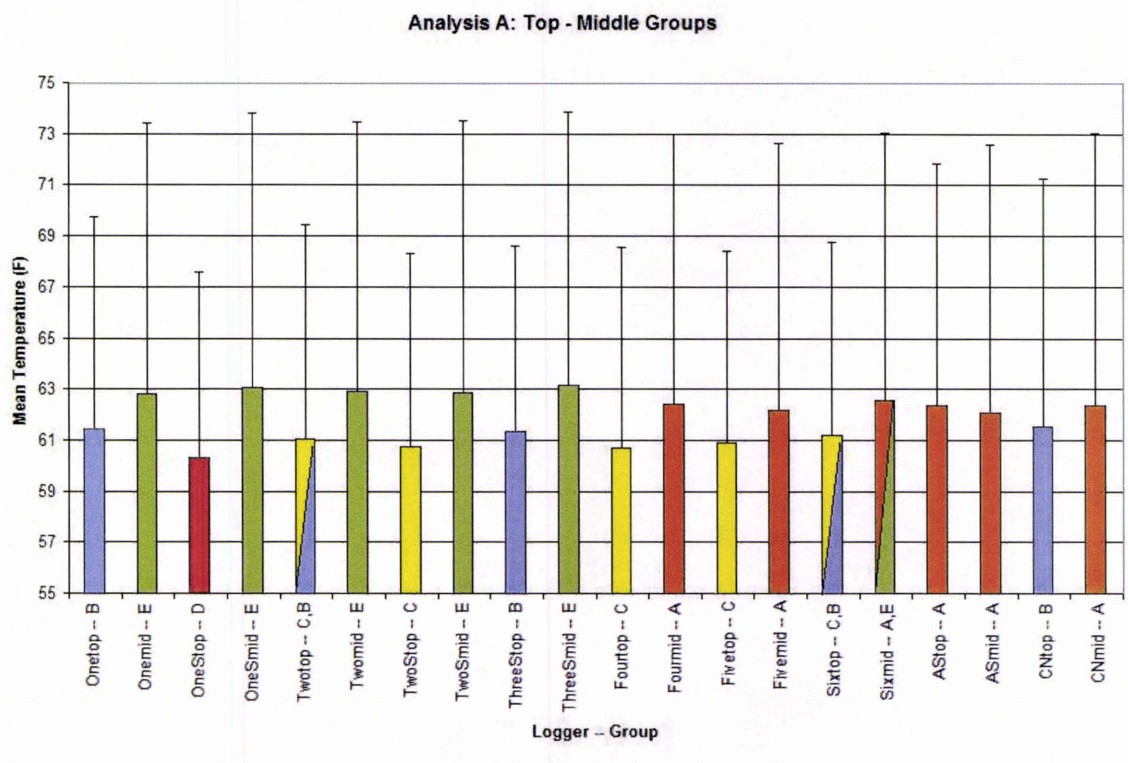


Figure 14. Analysis A, G1 – G2 portion, showing standard deviation and mean temperatures of each logger, logger groups are color-coded.

might group with a top or bottom logger at any particular location. In the G1-G2 portion the top logger ASt and the middle logger ASm actually fall into the same group while in the G2-G3 analysis the bottom logger ASb and the middle logger ASm group separately. This pattern of grouping would seem to indicate a location of ground water recharge, where in-flowing surface water was strongly influencing the subsurface temperatures. This indication would be stronger had the bottom logger ASb grouped by itself or with medium loggers rather than with other bottom loggers.

The reverse situation is observed at the 1S location wherein the G2-G3 analysis, the middle logger 1Sm grouped with a number of bottom loggers and in the G1-G2 analysis the 1Sm logger grouped by itself entirely. This pattern of groupings suggests that the 1S location is an area dominated by ground water discharge into the ditch. A third location of note in this set of comparisons is the TwoS location, which groups by itself in the G2-G3 analysis. It is likely that any logger not grouped with loggers from a similar horizon, such as is the case with the TwoSb logger in the G2-G3 analysis, is being influenced by hyporheic exchange in some way. In such a case it may or may not be possible to make any assumptions as how that locations is being influenced.

Analysis B (Summer Data)

This analysis used data collected from June 19, 2008 through August 20, 2008 (Figure 15). Figures 16 and 17 are the histogram and boxplot for the G1-G2 and G2-G3 portions of the analysis. A visual inspection of the histogram for both the G1-G2 and G2-G3 portions of the analysis show normally distributed data. The box plot for the G2-G3 portion shows generally equal variance in the data set. The box plot for the G1-G2 portion, however, does not display a sample set with equal variance. The robust nature of the ANOVA test with respect to samples of equal size and large samples sets should mitigate error in the statistical analysis (Zar 1996). ANOVA results for the G1-G2 comparison are as follows: F(19,17570) = 1939.1 (2.2e-16). The resulting G1-G2 comparison indicates two or more statistically significant populations, significant at

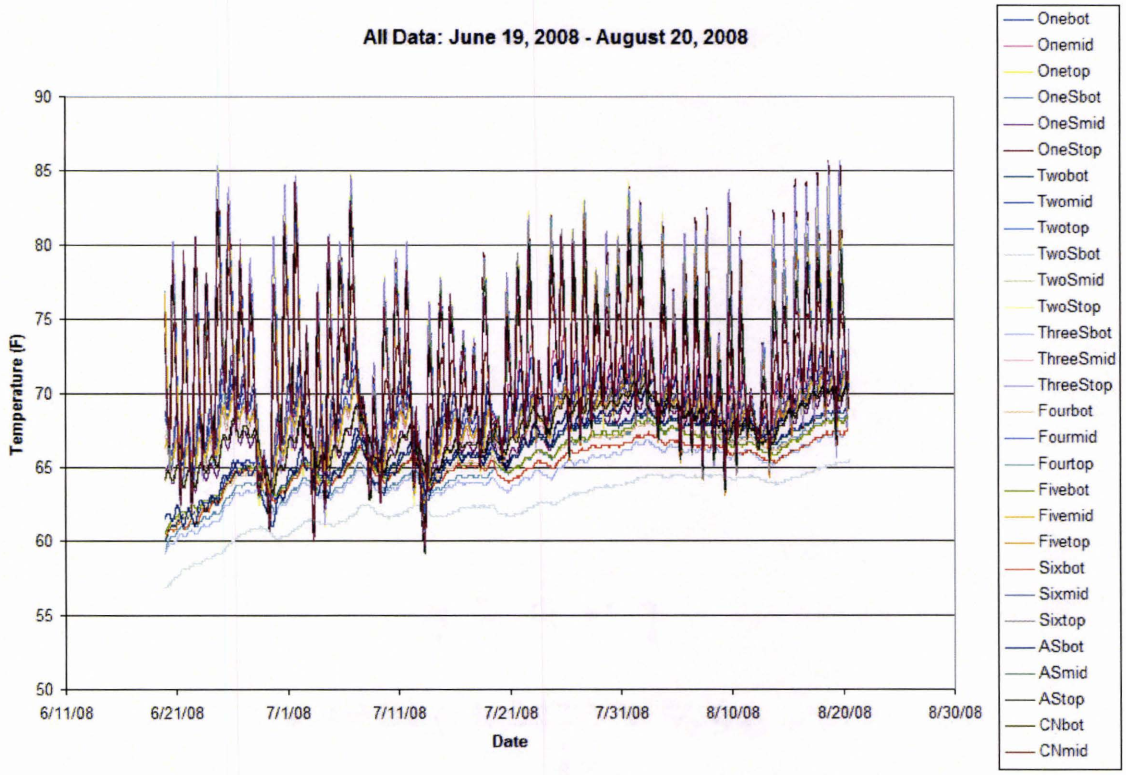
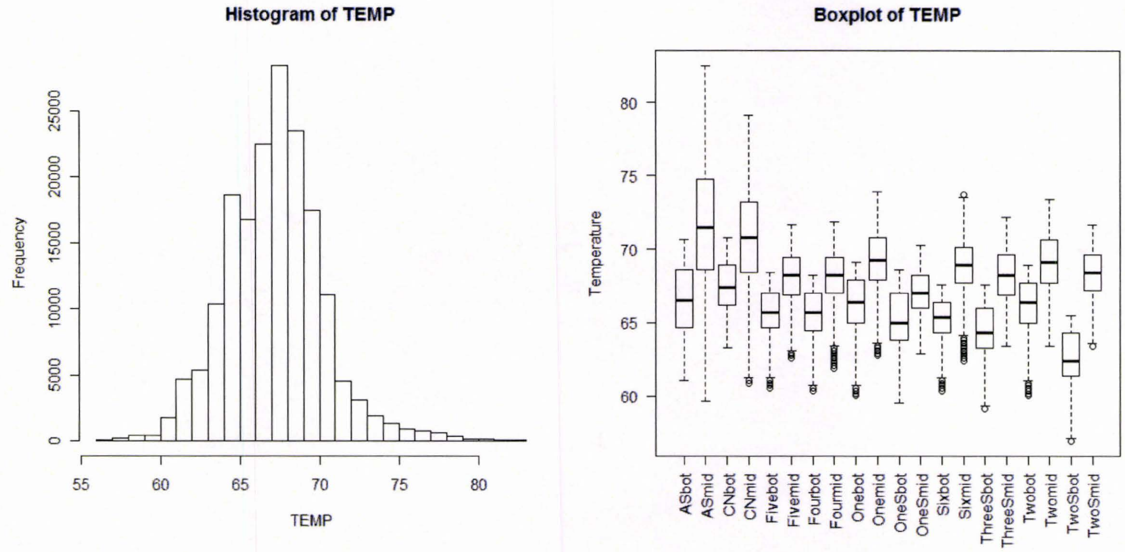
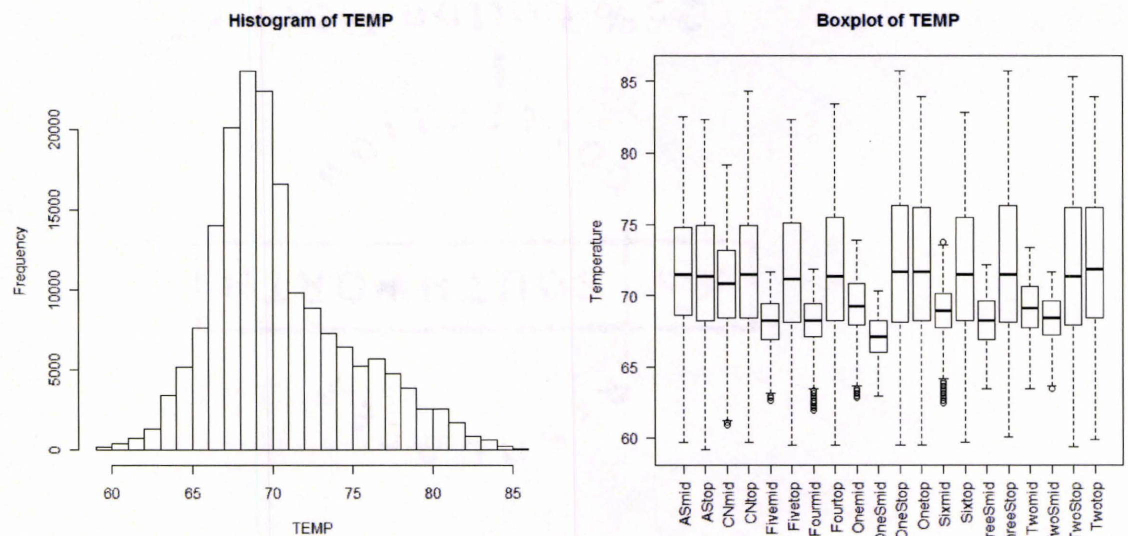


Figure 15. Plot of data used in analysis B (Appendix E)



a.) b.)

Figure 16: Analysis B, G2 – G3 portion. a.) Histogram. b.) Boxplot.



a.) b.)

Figure 17: Analysis B, G1 – G2 portion. a.) Histogram. b.) Boxplot.

95% and to 99%. Figure 18 shows Tukey's test results and groupings. ANOVA results for the G2-G3 comparison are as follows: F(19,175700) = 9356.2 (2.2e-16). The resulting G1-G2 comparison indicates two or more statistically significant populations, significant at 95% and to 99%. Figure 19 shows Tukey's test results and groupings.

This analysis shows the same results for the AS location as are described in Analysis A, thus similar conclusions are reached. Unique to the G2-G3 portion of analysis B, there were fewer pairs of loggers that were identified as statistically similar by Tukey's test, thus there was a greater number groups identified during the analysis. The first thought regarding the lack of statistically similar pairings was that there might have been a breakdown in the results from Tukey's test possibly the result of violated assumptions. After further review of both the histogram and box plot for the

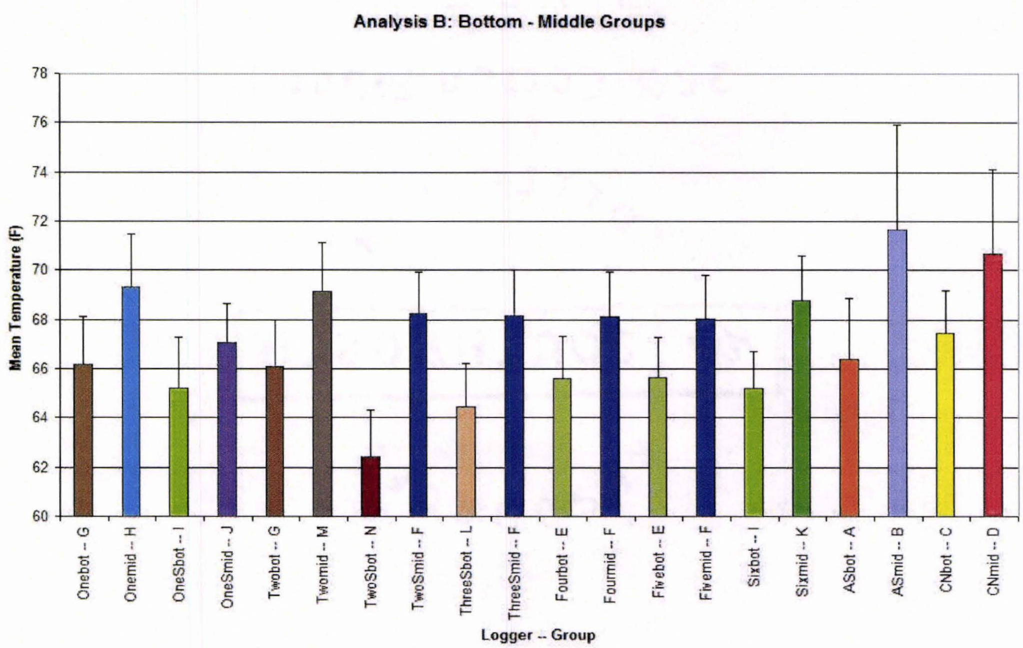


Figure 18. Analysis B, G2 – G3 portion, showing standard deviation and mean temperatures of each logger, logger groups are color-coded.

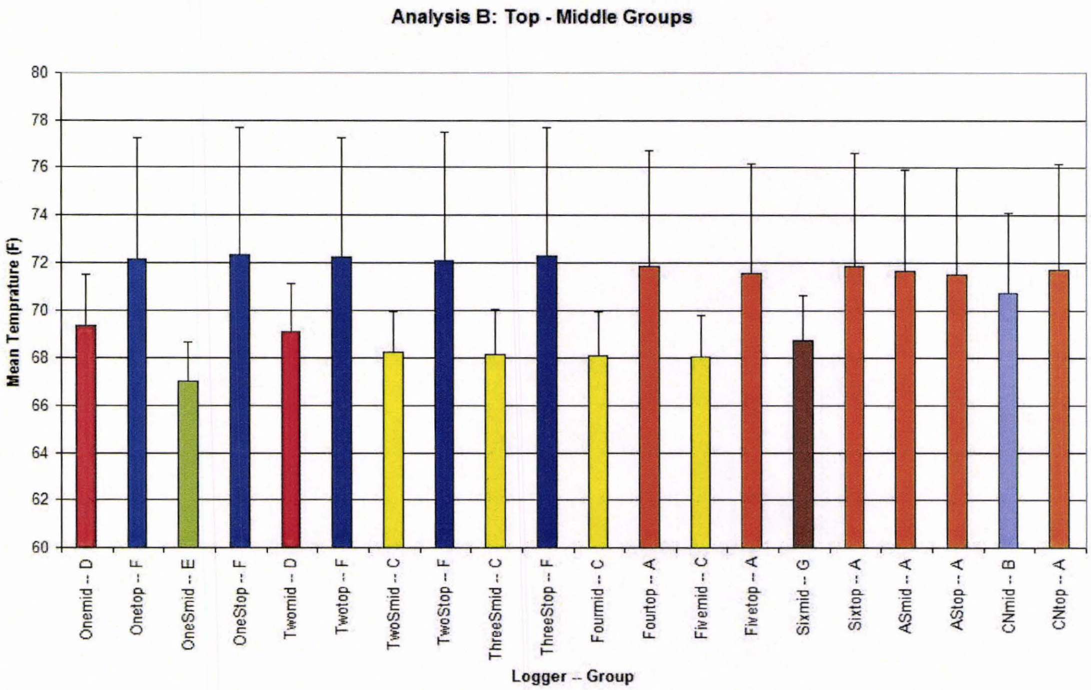


Figure 19. Analysis B, G1 – G2 portion, showing standard deviation and mean temperatures of each logger, logger groups are color-coded.

G2-G3 portion it was determined that the data exhibited a normal distribution and due to the robust nature of the Tukey's test the differences of variance depicted on the box plot is not of a magnitude that would invalidate the test results. Thus the groupings observed in the G2-G3 portion of the analysis are considered accurate, leading to the interpretation that over the monitoring period there is substantial variability observed from one location to the next in regards to the ground water surface water interface. This observation of increased variability leads to a conclusion that the summer months might be the best time to observe changing patterns of hyporheic exchange. Which makes sense because during the summer months you are more likely to have a greater difference between surface and ground water temperatures.

Analysis C (Fall Data)

The analysis was performed on data collected September 1, 2008 through November 1, 2008 (Figure 20). A visual inspection of the histograms generated for the G1-G2 or G2-G3 analysis revealed that neither exhibited a classic normal distribution, but the variance from a normal distribution does not appear to be of a magnitude to cause concern, again the ANOVA analysis is robust against violating the normal distribution of data assumption with large sample sizes and equally sized samples (Zar 1996). The box plots for the two comparisons both exhibit data sets with relatively equal variance (Figures 21 and 22). ANOVA results for the G1-G2 comparison are as follows: $F(19,175560) = 93.858$ (2.2e-16). The resulting G1-G2 comparison indicated two or more statistically significant populations, significant at 95% and to 99%.

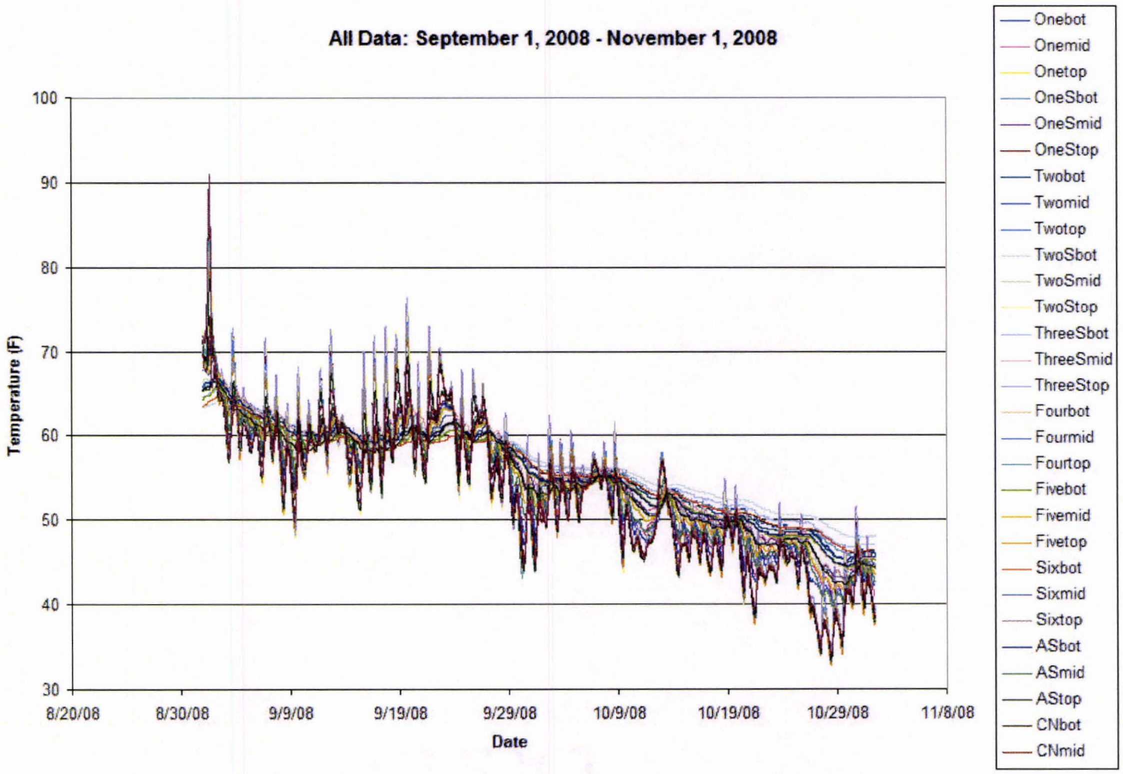
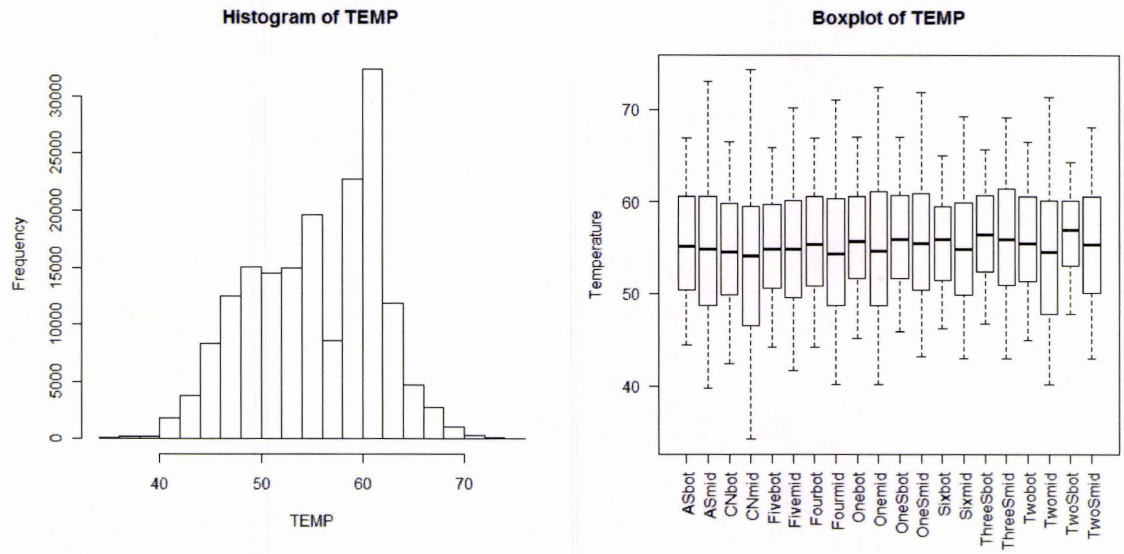
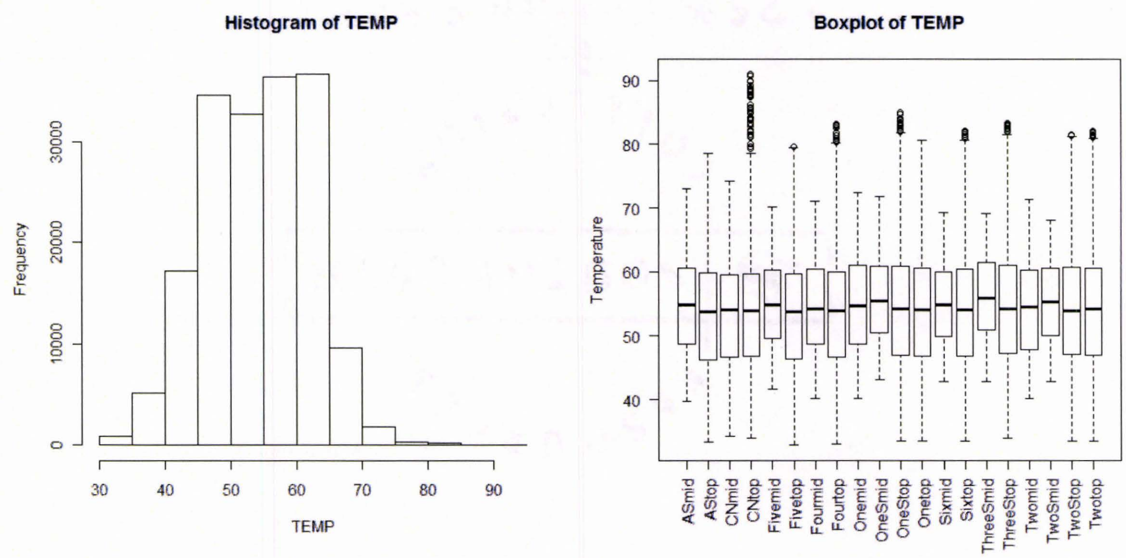


Figure 20: Plot of data used in analysis C. (Appendix F)



a.) b.)

Figure 21: Analysis C, G2 – G3 portion. a.) Histogram. b.) Boxplot.



a.) b.)

Figure 22: Analysis C, G1 – G2 portion. a.) Histogram. b.) Boxplot.

The Tukey's test results and groupings are shown in Figure 23. The ANOVA results for the G2-G3 comparison are as follows, F(19,175560) = 207.95 (2.2e-16). The resulting G1-G2 comparison indicated two or more statistically significant populations, significant at 95% and to 99%. Figure 24 depicts the Tukey's test results and groupings.

The results from this analysis yielded another set of groups that when first reviewed led to thoughts that the analysis might not be accurate due to violated assumptions. Again the histogram and boxplot for this analyses were reassessed and it was determined that the deviation from a normal distribution and equal variance was not a concern due to the robust nature of the Tukey's test. Thus the groupings do appear to be accurate, although they are still anomalous for the reasons discussed below. In the G1- G2 analysis the loggers in Group A are a mix of top and middle loggers to the extent that one cannot make a determination as to which horizon the group represents. Ultimately it was determined that the anomalous results generated over this time period were the result of cooling surface temperatures. As surface temperatures drop, the surface water temperature, which started out warmer than middle and bottom temperatures crosses over and is actually cooler than ground water temperatures at the end of the period. As a result of this observation it was determined that any conclusions derived from this analysis would be questionable at best, as the groupings themselves are biased due to the greater temperature trend.

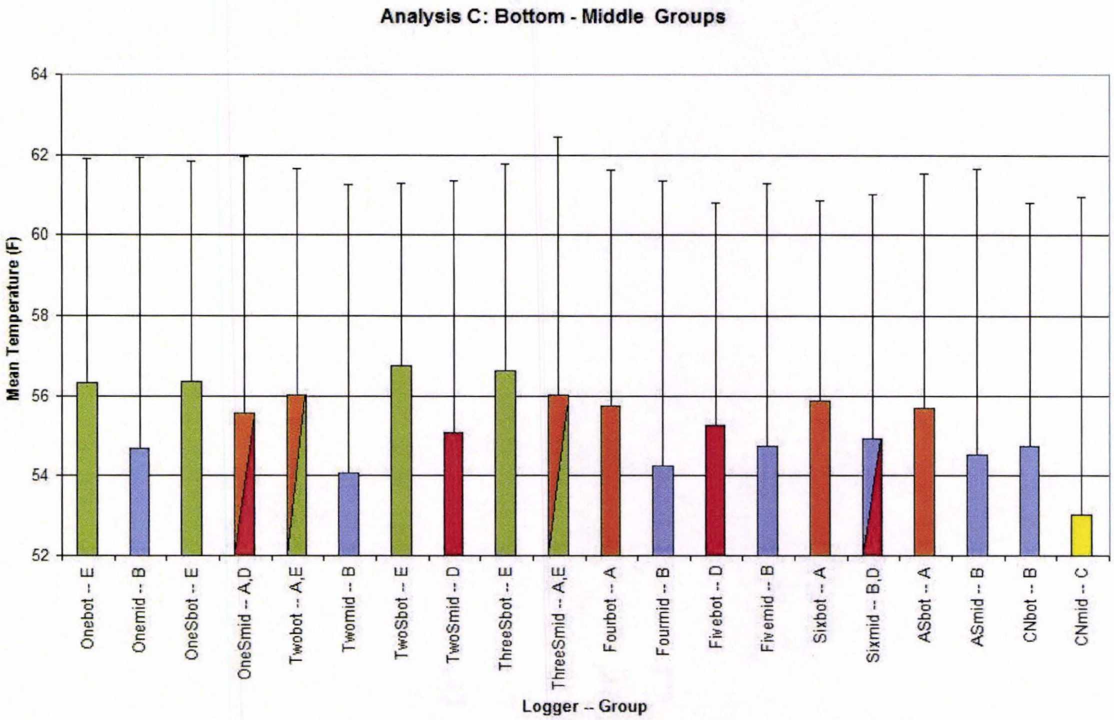


Figure 23: Analysis C, G2 – portion, showing standard deviation and mean temperatures of each logger, logger groups are color-coded.

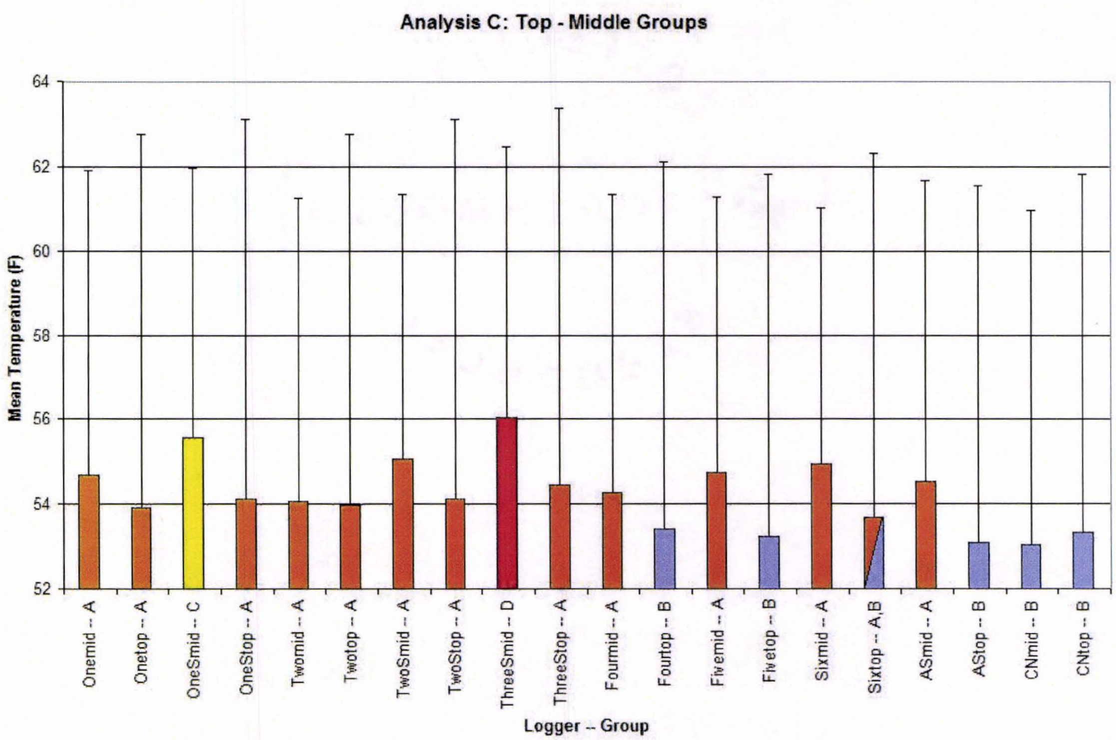


Figure 24: Analysis C, G1 – G2 portion, showing standard deviation and mean temperatures of each logger, logger groups are color-coded.

CHAPTER IV

DISCUSSION AND CONCLUSIONS

The methods outlined and implemented in this work suggested unique patterns of hyporheic interaction at several locations in the ditch. As discussed in the individual analyses presented above, the AS and OneS locations both yielded results that allow for a determination regarding the directionality of hyporheic exchange. At the AS location groupings generated by both Analysis A and B indicated the likelihood that the location is one dominated by ground water recharge. This observation is supported to some extent by the types of soils observed near the AS location, which consisted of a coarser more gravelly sand than along other portions of the reach. In the absence of other factors, such as high water table that might prevent infiltration, the coarser sediments at the AS location would allow for infiltration more so than a clay rich soil. The AS location also happened to be located in a portion of the reach where the ditch was generally narrower than sections to the south. Given the relatively consistent water supply to the ditch one would expect that if the volume of water being transported by the ditch was constant through out the ditch, that a narrowing of the channel profile would yield deeper water levels and/or higher water velocities. The depth of the water across the AS location however was typically shallower then other portions of the ditch. The shallow water level associated with a narrower ditch profile at this location suggests that surface water is being lost to the ground water system. These indications that the AS location appears to be dominated by ground water recharge is particularly important due to its proximity to the Crookston Wellhead Protection Area (WHPA), as conditions at this location are very similar to conditions observed across portions of the ditch that do fall within the WHPA. Concerning the One S location, the resulting groups generated from Analysis A seem to indicate that the location is dominated by ground water discharge. In contrast to the AS location, the soils observed around the OneS location have a much higher clay content, and the ditch is wider and shallower. The depth of the water across the OneS location was somewhat deeper then observed at similar locations along the ditch but this is likely due to the existence of a culvert just north of the OneS location restricting flow. The observations as noted above indicate the likelihood that each of the locations appears to be dominated either by ground water recharge or by ground water discharge.

The resulting observations from the G2-G3 portion of Analysis B indicate an increase in variability from one location to the next during the summer months. The Tukey's test for this portion of the analysis yielded fewer statistically similar logger pairs. Fewer pairings lead to more individual groups being identified and to these groups consisting of a fewer number of individual loggers. This observation of an apparent increased variability leads to a conclusion that the summer months might be an ideal time to observe changing patterns of hyporheic exchange. Intuitively this observation makes sense especially with respect to projects using heat as an indicator of surface water/ground water exchange, as it is likely that the temperature gradient between surface water and ground water will be will be the greatest during the summer months.

The methodology developed does not directly yield a rate of hyporheic exchange, although given a measurement of hydraulic conductivity and hydraulic head at a point in time for a location should allow such a rate to be approximated. It might also be possible to make assumptions of rate in relationship to nearby locations. Deployment of the loggers in a closely spaced array over a small reach might yield the best data for such a determination.

Ultimately, the study yielded a limited number of direct conclusions as to the directionality of water exchange across the hyporheic zone and no definitive determination as to the rate of water exchange across the hyporheic zone along the ditch. Despite this, the methodology developed during this project appears to be ideal for the processing of the large data sets generated by using data logger instrumentation. The resulting analyses can indicate the directionality of hyporheic exchange at an instrumented location. It appears that the methodology developed might best be used as a tool in ditch reconnaissance. The method can easily and cost-effectively be used to identify specific reaches within a larger study area where further instrumentation with piezometers, flow meters, and water level loggers may yield more definitive results on hyporheic exchange direction and rate.

To minimize the potential for error in the statistical analysis, it is important when using this methodology that sample sizes be both large and equal for each location. It is also important to examine large-scale trends in the data such as was observed and described above in Analysis C. The interval which is to be analyzed should be reviewed carefully for such large scale trend in the data to avoid biasing or skewing the results.

Ultimately, the results obtained during this study may or may not be of further use in evaluating the success of the reclamation work at the ditch. Unfortunately, shortly after the completing reclamation work at the ditch, a change in operations at the gravel pit resulted in an increase of discharge into the ditch that altered the flow. Both the reclamation work and the increased flow rate will likely change the hyporheic zone interactions along the ditch.

Recommendations for Further Study

There is much potential for further work both in the study area and on the data generated during this study. One such potential study would be to complete a similar post-reclamation study and compare the results before and after reclamation, although the comparison will be difficult due to the changes in flow characteristics discussed above. Another potential direction for further research would be to determine if there is an optimal frequency at which data could be collected for future statistical work or for future deployment of the loggers. Because this data set was generated on a 10-min interval, it would be simple to extract subsets of data to represent a longer time frequency.

Other potential options involve deploying the loggers differently or in changing how the statistical analyses are performed. For example, the loggers could be deployed in an array across and along a portion of the ditch and the data generated could be analyzed using the methodology described above. An ANOVA analysis followed by Tukey's test could be run on loggers from a single horizon. The resulting groupings may be of use in mapping hyporheic exchange zones or possibly in determining rates of exchange relative to surrounding loggers.

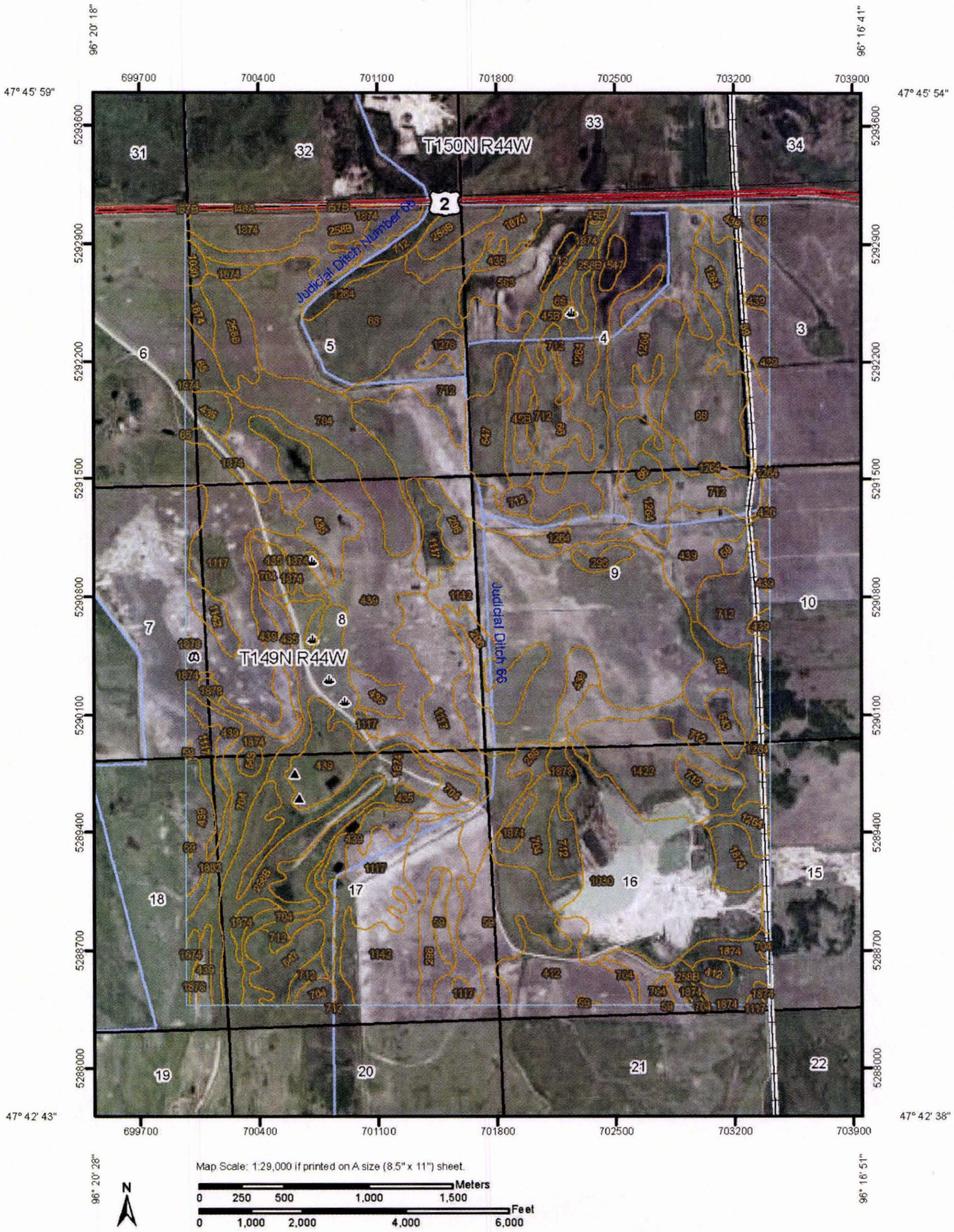
Another potential avenue would be to further analyze the data set collected during this study. It may be useful to run an analysis on smaller subsets of the larger data set with respect to atmospheric events such as storm events or heat waves. One could analyze the data for a time period before, during and after the event in an effort to determine how such an atmospheric event might affect hyporheic exchange. One other potential use for this data set generated would be to run an analysis in such a way as to identify changes in hyporheic interaction with respect to shorter time periods. A series of consecutive short time period analysis conducted over several weeks or months of data, might identify short term changes in hyporheic activity. Such short-term changes in activity might indicate periods where hyporheic exchange is influenced by a temporarily high or low water table, or some other influencing factor.

APPENDICES

Appendix A

NRCS Soil Web Mapper Survey

Soil Map—Polk County, Minnesota, and Red Lake County, Minnesota
(Judicial Ditch 66)



USDA Natural Resources Conservation Service

Web Soil Survey
National Cooperative Soil Survey

11/15/2010
Page 1 of 3

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils
- Soil Map Units

Special Point Features
- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other

Special Line Features
- Gully
- Short Steep Slope
- Other

Political Features
- Cities
- PLSS Township and Range
- PLSS Section

Water Features
- Oceans
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

MAP INFORMATION

Map Scale: 1:29,000 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at scales ranging from 1:12,000 to 1:20,000.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: UTM Zone 14N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Polk County, Minnesota
Survey Area Data: Version 6, Mar 25, 2009

Soil Survey Area: Red Lake County, Minnesota
Survey Area Data: Version 7, Mar 30, 2009

Your area of interest (AOI) includes more than one soil survey area. These survey areas may have been mapped at different scales, with a different land use in mind, at different times, or at different levels of detail. This may result in map unit symbols, soil properties, and interpretations that do not completely agree across soil survey area boundaries.

Date(s) aerial images were photographed: 6/20/2003; 6/30/2003

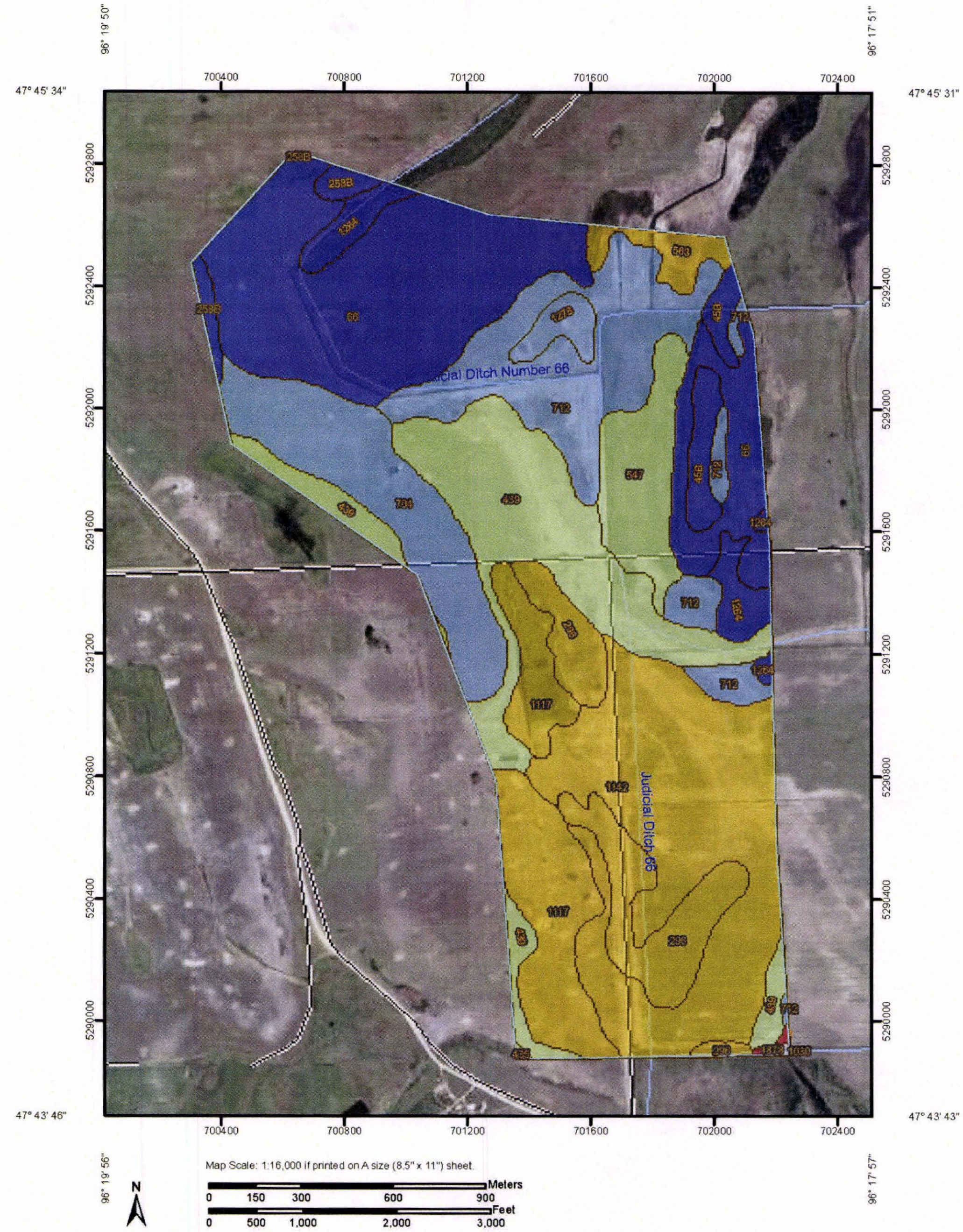
The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Polk County, Minnesota (MN119)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
45B	Maddock loamy fine sand, 1 to 6 percent slopes	31.0	0.8%
59	Grimstad fine sandy loam	151.2	3.7%
65	Foxhome sandy loam	16.1	0.4%
66	Flaming loamy fine sand	310.1	7.7%
258B	Sandberg loamy sand, 1 to 6 percent slopes	205.9	5.1%
296	Fram loam	89.1	2.2%
412	Mavie fine sandy loam	69.8	1.7%
426	Foldahl loamy fine sand	0.7	0.0%
435	Syrene sandy loam	129.4	3.2%
439	Strathcona fine sandy loam	500.8	12.4%
543	Markey muck	19.1	0.5%
547	Deerwood muck	112.8	2.8%
563	Northwood muck	54.9	1.4%
704	Wyrene sandy loam	238.5	5.9%
712	Rosewood fine sandy loam	455.4	11.2%
1030	Pits, gravel-udipsamments complex	209.4	5.2%
1117	Hedman loam	330.6	8.2%
1142	Hedman-Fram complex	426.0	10.5%
1264	Ulen loamy fine sand	219.7	5.4%
1278	Rosewood-Venlo complex	9.0	0.2%
1422	Northwood muck, marl subsoil	87.0	2.1%
1874	Radium loamy sand	349.2	8.6%
1878	Hamre muck	19.7	0.5%
1882	Rosewood, Strathcona, and Berner soils, seepy	9.5	0.2%
Subtotals for Soil Survey Area		**4,044.9**	**99.9%**
Totals for Area of Interest		**4,050.8**	**100.0%**

Red Lake County, Minnesota (MN125)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
I48A	Radium loamy sand, 0 to 3 percent slopes	4.9	0.1%
I57B	Sandberg-Radium complex, 1 to 6 percent slopes	1.1	0.0%
Subtotals for Soil Survey Area		**6.0**	**0.1%**
Totals for Area of Interest		**4,050.8**	**100.0%**

Percent Sand—Polk County, Minnesota
(Judicial Ditch 66)



MAP LEGEND

Area of Interest (AOI)

- Area of Interest (AOI)

Soils

- Soil Map Units

Soil Ratings

- <= 34.1
- > 34.1 AND <= 54.9
- > 54.9 AND <= 74.8
- > 74.8 AND <= 87.6
- > 87.6 AND <= 91.7
- Not rated or not available

Political Features

- Cities

Water Features

- Oceans
- Streams and Canals

Transportation

- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

MAP INFORMATION

Map Scale: 1:16,000 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:20,000.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: UTM Zone 14N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Polk County, Minnesota
Survey Area Data: Version 6, Mar 25, 2009

Date(s) aerial images were photographed: 6/20/2003

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Percent Sand

Percent Sand— Summary by Map Unit — Polk County, Minnesota				
Map unit symbol	Map unit name	Rating (percent)	Acres in AOI	Percent of AOI
45B	Maddock loamy fine sand, 1 to 6 percent slopes	88.9	16.3	1.9%
66	Flaming loamy fine sand	91.7	178.8	20.9%
258B	Sandberg loamy sand, 1 to 6 percent slopes	88.9	8.2	1.0%
296	Fram loam	48.8	54.2	6.3%
435	Syrene sandy loam	74.8	0.4	0.0%
439	Strathcona fine sandy loam	68.6	119.7	14.0%
547	Deerwood muck	73.0	37.5	4.4%
563	Northwood muck	53.4	11.5	1.3%
704	Wyrene sandy loam	83.1	72.9	8.5%
712	Rosewood fine sandy loam	87.6	100.5	11.8%
1030	Pits, gravel-udipsamments complex		0.3	0.0%
1117	Hedman loam	54.9	69.2	8.1%
1142	Hedman-Fram complex	54.8	154.2	18.0%
1264	Ulen loamy fine sand	89.8	21.6	2.5%
1278	Rosewood-Venlo complex	86.1	9.0	1.1%
1878	Hamre muck	34.1	1.1	0.1%
Totals for Area of Interest			855.4	100.0%

Description

Sand as a soil separate consists of mineral soil particles that are 0.05 millimeter to 2 millimeters in diameter. In the database, the estimated sand content of each soil layer is given as a percentage, by weight, of the soil material that is less than 2 millimeters in diameter. The content of sand, silt, and clay affects the physical behavior of a soil. Particle size is important for engineering and agronomic interpretations, for determination of soil hydrologic qualities, and for soil classification.

For each soil layer, this attribute is actually recorded as three separate values in the database. A low value and a high value indicate the range of this attribute for the soil component. A "representative" value indicates the expected value of this attribute for the component. For this soil property, only the representative value is used.

Rating Options

Units of Measure: percent

Aggregation Method: Dominant Component

Component Percent Cutoff: None Specified

Tie-break Rule: Higher

Interpret Nulls as Zero: No

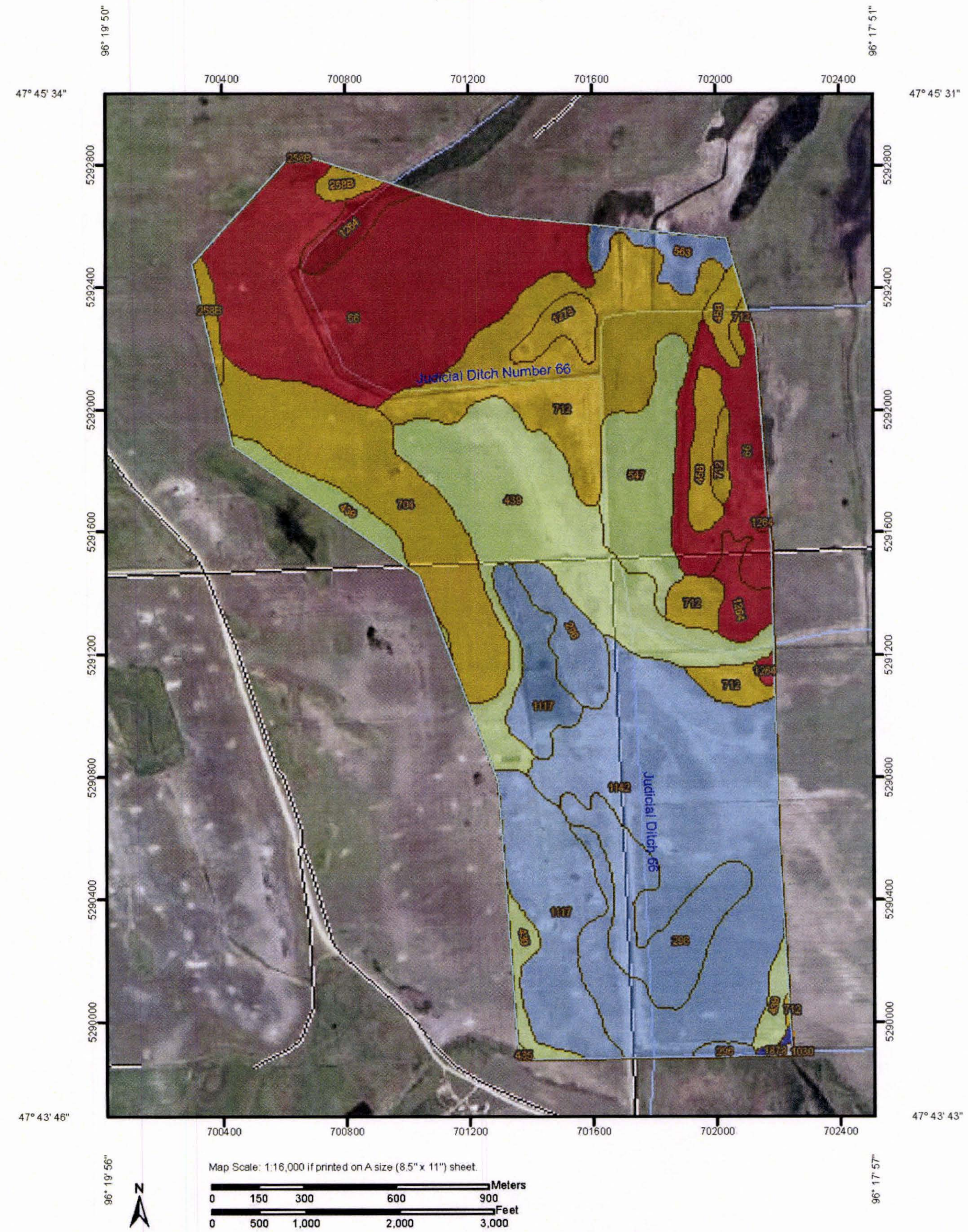
Layer Options: Depth Range

Top Depth: 1

Bottom Depth: 60

Units of Measure: Inches

Percent Silt—Polk County, Minnesota
(Judicial Ditch 66)



USDA Natural Resources Conservation Service

Web Soil Survey
National Cooperative Soil Survey

3/14/2011
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MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils
- Soil Map Units

Soil Ratings
- <= 4.7
- > 4.7 AND <= 10.9
- > 10.9 AND <= 20.2
- > 20.2 AND <= 36.8
- > 36.8 AND <= 44.4
- Not rated or not available

Political Features
- Cities

Water Features
- Oceans
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

MAP INFORMATION

Map Scale: 1:16,000 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:20,000.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: UTM Zone 14N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Polk County, Minnesota
Survey Area Data: Version 6, Mar 25, 2009

Date(s) aerial images were photographed: 6/20/2003

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Percent Silt

Percent Silt— Summary by Map Unit — Polk County, Minnesota				
Map unit symbol	Map unit name	Rating (percent)	Acres in AOI	Percent of AOI
45B	Maddock loamy fine sand, 1 to 6 percent slopes	6.8	16.3	1.9%
66	Flaming loamy fine sand	2.3	178.8	20.9%
258B	Sandberg loamy sand, 1 to 6 percent slopes	7.2	8.2	1.0%
296	Fram loam	36.8	54.2	6.3%
435	Syrene sandy loam	18.9	0.4	0.0%
439	Strathcona fine sandy loam	16.7	119.7	14.0%
547	Deerwood muck	20.2	37.5	4.4%
563	Northwood muck	31.9	11.5	1.3%
704	Wyrene sandy loam	10.9	72.9	8.5%
712	Rosewood fine sandy loam	6.3	100.5	11.8%
1030	Pits, gravel-udipsamments complex		0.3	0.0%
1117	Hedman loam	34.1	69.2	8.1%
1142	Hedman-Fram complex	31.0	154.2	18.0%
1264	Ulen loamy fine sand	4.7	21.6	2.5%
1278	Rosewood-Venlo complex	6.9	9.0	1.1%
1878	Hamre muck	44.4	1.1	0.1%
Totals for Area of Interest			855.4	100.0%

Description

Silt as a soil separate consists of mineral soil particles that are 0.002 to 0.05 millimeter in diameter. In the database, the estimated silt content of each soil layer is given as a percentage, by weight, of the soil material that is less than 2 millimeters in diameter.

The content of sand, silt, and clay affects the physical behavior of a soil. Particle size is important for engineering and agronomic interpretations, for determination of soil hydrologic qualities, and for soil classification

For each soil layer, this attribute is actually recorded as three separate values in the database. A low value and a high value indicate the range of this attribute for the soil component. A "representative" value indicates the expected value of this attribute for the component. For this soil property, only the representative value is used.

Rating Options

Units of Measure: percent

Aggregation Method: Dominant Component

Component Percent Cutoff: *None Specified*

Tie-break Rule: Higher

Interpret Nulls as Zero: No

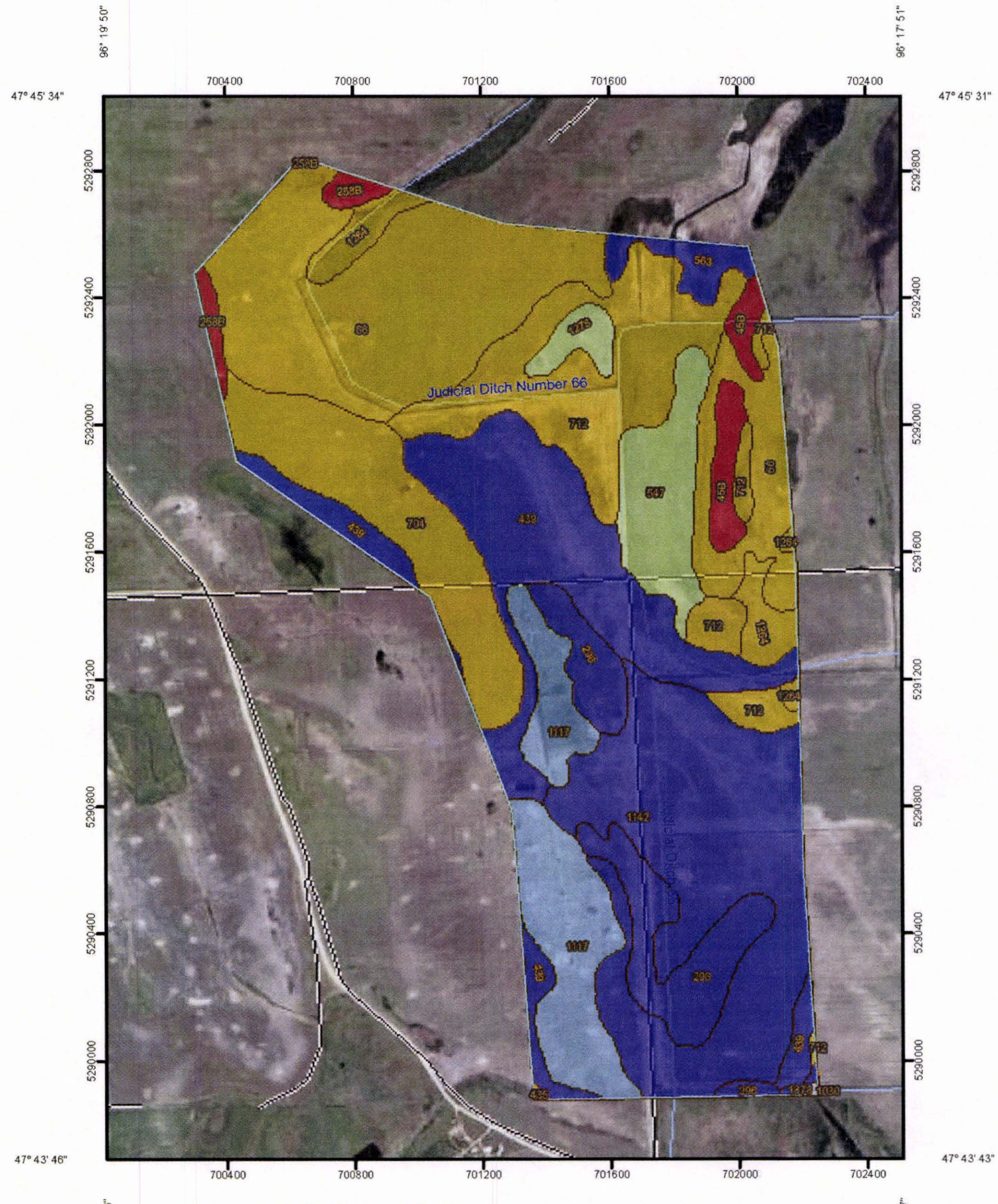
Layer Options: Depth Range

Top Depth: 1

Bottom Depth: 60

Units of Measure: Inches

Percent Clay—Polk County, Minnesota
(Judicial Ditch 66)



Map Scale: 1:16,000 if printed on A size (8.5" x 11") sheet.

N

Meters: 0 150 300 600 900

Feet: 0 500 1,000 2,000 3,000

Percent Clay–Polk County, Minnesota
(Judicial Ditch 66)

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils
- Soil Map Units

Soil Ratings
- <= 4.3
- > 4.3 AND <= 6.2
- > 6.2 AND <= 7
- > 7 AND <= 11
- > 11 AND <= 21.5
- Not rated or not available

Political Features
- Cities

Water Features
- Oceans
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

MAP INFORMATION

Map Scale: 1:16,000 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:20,000.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: UTM Zone 14N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Polk County, Minnesota
Survey Area Data: Version 6, Mar 25, 2009

Date(s) aerial images were photographed: 6/20/2003

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Percent Clay

Percent Clay— Summary by Map Unit — Polk County, Minnesota				
Map unit symbol	Map unit name	Rating (percent)	Acres in AOI	Percent of AOI
45B	Maddock loamy fine sand, 1 to 6 percent slopes	4.3	16.3	1.9%
66	Flaming loamy fine sand	6.0	178.8	20.9%
258B	Sandberg loamy sand, 1 to 6 percent slopes	3.9	8.2	1.0%
296	Fram loam	14.4	54.2	6.3%
435	Syrene sandy loam	6.2	0.4	0.0%
439	Strathcona fine sandy loam	14.7	119.7	14.0%
547	Deerwood muck	6.8	37.5	4.4%
563	Northwood muck	14.7	11.5	1.3%
704	Wyrene sandy loam	6.0	72.9	8.5%
712	Rosewood fine sandy loam	6.1	100.5	11.8%
1030	Pits, gravel-udipsamments complex		0.3	0.0%
1117	Hedman loam	11.0	69.2	8.1%
1142	Hedman-Fram complex	14.1	154.2	18.0%
1264	Ulen loamy fine sand	5.5	21.6	2.5%
1278	Rosewood-Venlo complex	7.0	9.0	1.1%
1878	Hamre muck	21.5	1.1	0.1%
Totals for Area of Interest			**855.4**	**100.0%**

Description

Clay as a soil separate consists of mineral soil particles that are less than 0.002 millimeter in diameter. The estimated clay content of each soil layer is given as a percentage, by weight, of the soil material that is less than 2 millimeters in diameter. The amount and kind of clay affect the fertility and physical condition of the soil and the ability of the soil to adsorb cations and to retain moisture. They influence shrink-swell potential, saturated hydraulic conductivity (Ksat), plasticity, the ease of soil dispersion, and other soil properties. The amount and kind of clay in a soil also affect tillage and earth-moving operations.

Most of the material is in one of three groups of clay minerals or a mixture of these clay minerals. The groups are kaolinite, smectite, and hydrous mica, the best known member of which is illite.

For each soil layer, this attribute is actually recorded as three separate values in the database. A low value and a high value indicate the range of this attribute for the soil component. A "representative" value indicates the expected value of this attribute for the component. For this soil property, only the representative value is used.

Rating Options

Units of Measure: percent

Aggregation Method: Dominant Component

Component Percent Cutoff: *None Specified*

Tie-break Rule: Higher

Interpret Nulls as Zero: No

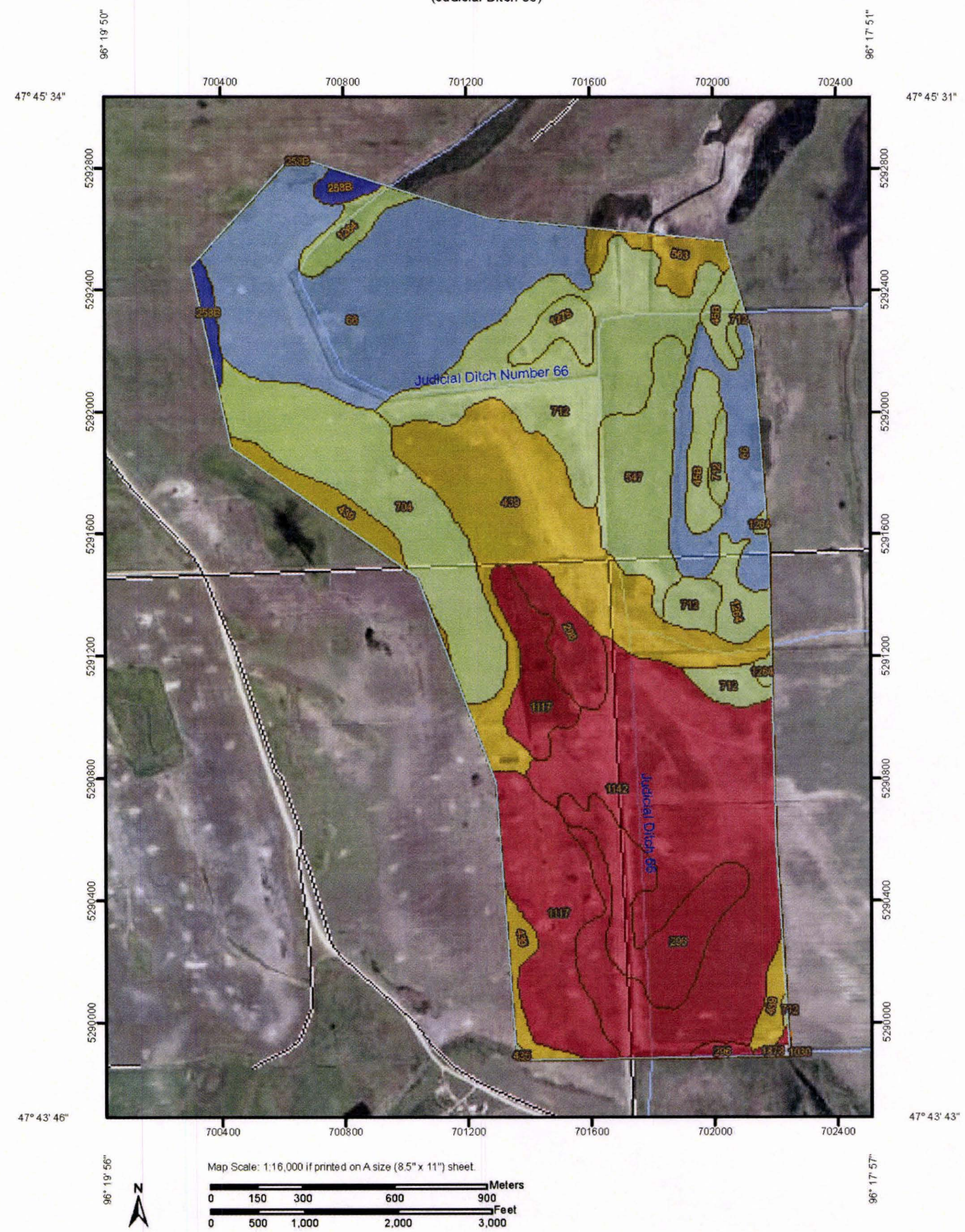
Layer Options: Depth Range

Top Depth: 1

Bottom Depth: 60

Units of Measure: Inches

Saturated Hydraulic Conductivity (Ksat)—Polk County, Minnesota
(Judicial Ditch 66)



Map Scale: 1:16,000 if printed on A size (8.5" x 11") sheet.

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils
- Soil Map Units

Soil Ratings
- <= 10.8953
- > 10.8953 AND <= 41.0568
- > 41.0568 AND <= 80.6568
- > 80.6568 AND <= 91.74
- > 91.74 AND <= 162.766
- Not rated or not available

Political Features
- Cities

Water Features
- Oceans
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

MAP INFORMATION

Map Scale: 1:16,000 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:20,000.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: UTM Zone 14N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Polk County, Minnesota
Survey Area Data: Version 6, Mar 25, 2009

Date(s) aerial images were photographed: 6/20/2003

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Saturated Hydraulic Conductivity (Ksat)

Saturated Hydraulic Conductivity (Ksat)— Summary by Map Unit — Polk County, Minnesota				
Map unit symbol	Map unit name	Rating (micrometers per second)	Acres in AOI	Percent of AOI
45B	Maddock loamy fine sand, 1 to 6 percent slopes	77.6300	16.3	1.9%
66	Flaming loamy fine sand	91.7400	178.8	20.9%
258B	Sandberg loamy sand, 1 to 6 percent slopes	162.7660	8.2	1.0%
296	Fram loam	9.1700	54.2	6.3%
435	Syrene sandy loam	70.2136	0.4	0.0%
439	Strathcona fine sandy loam	32.5741	119.7	14.0%
547	Deerwood muck	71.2309	37.5	4.4%
563	Northwood muck	41.0568	11.5	1.3%
704	Wyrene sandy loam	70.4279	72.9	8.5%
712	Rosewood fine sandy loam	74.6903	100.5	11.8%
1030	Pits, gravel-udipsamments complex		0.3	0.0%
1117	Hedman loam	9.1700	69.2	8.1%
1142	Hedman-Fram complex	9.1700	154.2	18.0%
1264	Ulen loamy fine sand	80.6568	21.6	2.5%
1278	Rosewood-Venlo complex	74.6903	9.0	1.1%
1878	Hamre muck	10.8953	1.1	0.1%
Totals for Area of Interest			**855.4**	**100.0%**

Description

Saturated hydraulic conductivity (Ksat) refers to the ease with which pores in a saturated soil transmit water. The estimates are expressed in terms of micrometers per second. They are based on soil characteristics observed in the field, particularly structure, porosity, and texture. Saturated hydraulic conductivity is considered in the design of soil drainage systems and septic tank absorption fields.

For each soil layer, this attribute is actually recorded as three separate values in the database. A low value and a high value indicate the range of this attribute for the soil component. A "representative" value indicates the expected value of this attribute for the component. For this soil property, only the representative value is used.

The numeric Ksat values have been grouped according to standard Ksat class limits.

Rating Options

Units of Measure: micrometers per second

Aggregation Method: Dominant Component

Component Percent Cutoff: *None Specified*

Tie-break Rule: Fastest

Interpret Nulls as Zero: No

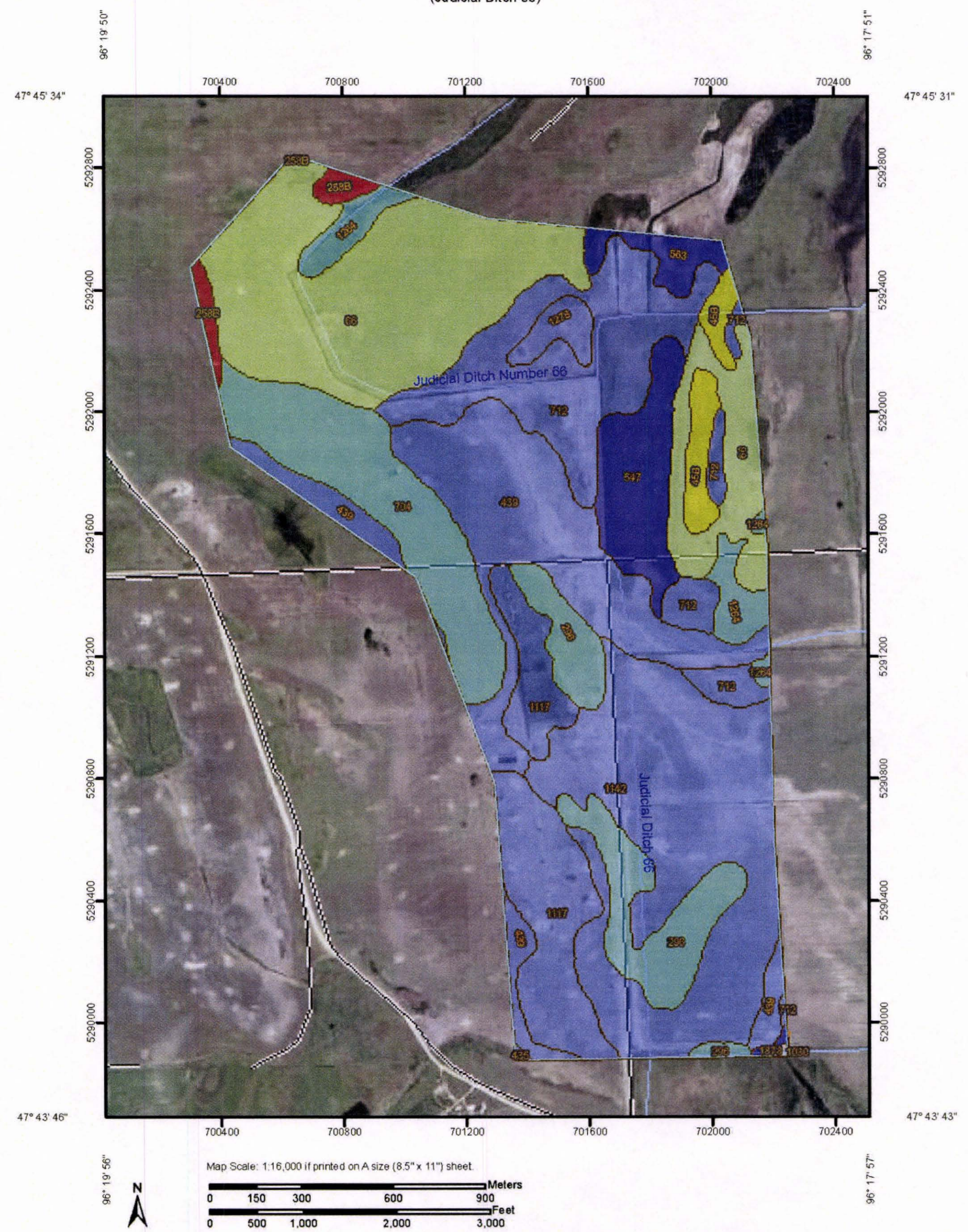
Layer Options: Depth Range

Top Depth: 1

Bottom Depth: 60

Units of Measure: Inches

Drainage Class—Polk County, Minnesota
(Judicial Ditch 66)



USDA Natural Resources Conservation Service

Web Soil Survey
National Cooperative Soil Survey

3/14/2011
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MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils
- Soil Map Units

Soil Ratings
- Excessively drained
- Somewhat excessively drained
- Well drained
- Moderately well drained
- Somewhat poorly drained
- Poorly drained
- Very poorly drained
- Not rated or not available

Political Features
- Cities

Water Features
- Oceans
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

MAP INFORMATION

Map Scale: 1:16,000 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:20,000.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: UTM Zone 14N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Polk County, Minnesota
Survey Area Data: Version 6, Mar 25, 2009

Date(s) aerial images were photographed: 6/20/2003

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Drainage Class

Drainage Class— Summary by Map Unit — Polk County, Minnesota				
Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
45B	Maddock loamy fine sand, 1 to 6 percent slopes	Well drained	16.3	1.9%
66	Flaming loamy fine sand	Moderately well drained	178.8	20.9%
258B	Sandberg loamy sand, 1 to 6 percent slopes	Excessively drained	8.2	1.0%
296	Fram loam	Somewhat poorly drained	54.2	6.3%
435	Syrene sandy loam	Poorly drained	0.4	0.0%
439	Strathcona fine sandy loam	Poorly drained	119.7	14.0%
547	Deerwood muck	Very poorly drained	37.5	4.4%
563	Northwood muck	Very poorly drained	11.5	1.3%
704	Wyrene sandy loam	Somewhat poorly drained	72.9	8.5%
712	Rosewood fine sandy loam	Poorly drained	100.5	11.8%
1030	Pits, gravel-udipsamments complex		0.3	0.0%
1117	Hedman loam	Poorly drained	69.2	8.1%
1142	Hedman-Fram complex	Poorly drained	154.2	18.0%
1264	Ulen loamy fine sand	Somewhat poorly drained	21.6	2.5%
1278	Rosewood-Venlo complex	Poorly drained	9.0	1.1%
1878	Hamre muck	Very poorly drained	1.1	0.1%
Totals for Area of Interest			**855.4**	**100.0%**

Description

"Drainage class (natural)" refers to the frequency and duration of wet periods under conditions similar to those under which the soil formed. Alterations of the water regime by human activities, either through drainage or irrigation, are not a consideration unless they have significantly changed the morphology of the soil. Seven classes of natural soil drainage are recognized-excessively drained, somewhat excessively drained, well drained, moderately well drained, somewhat poorly drained, poorly drained, and very poorly drained. These classes are defined in the "Soil Survey Manual."

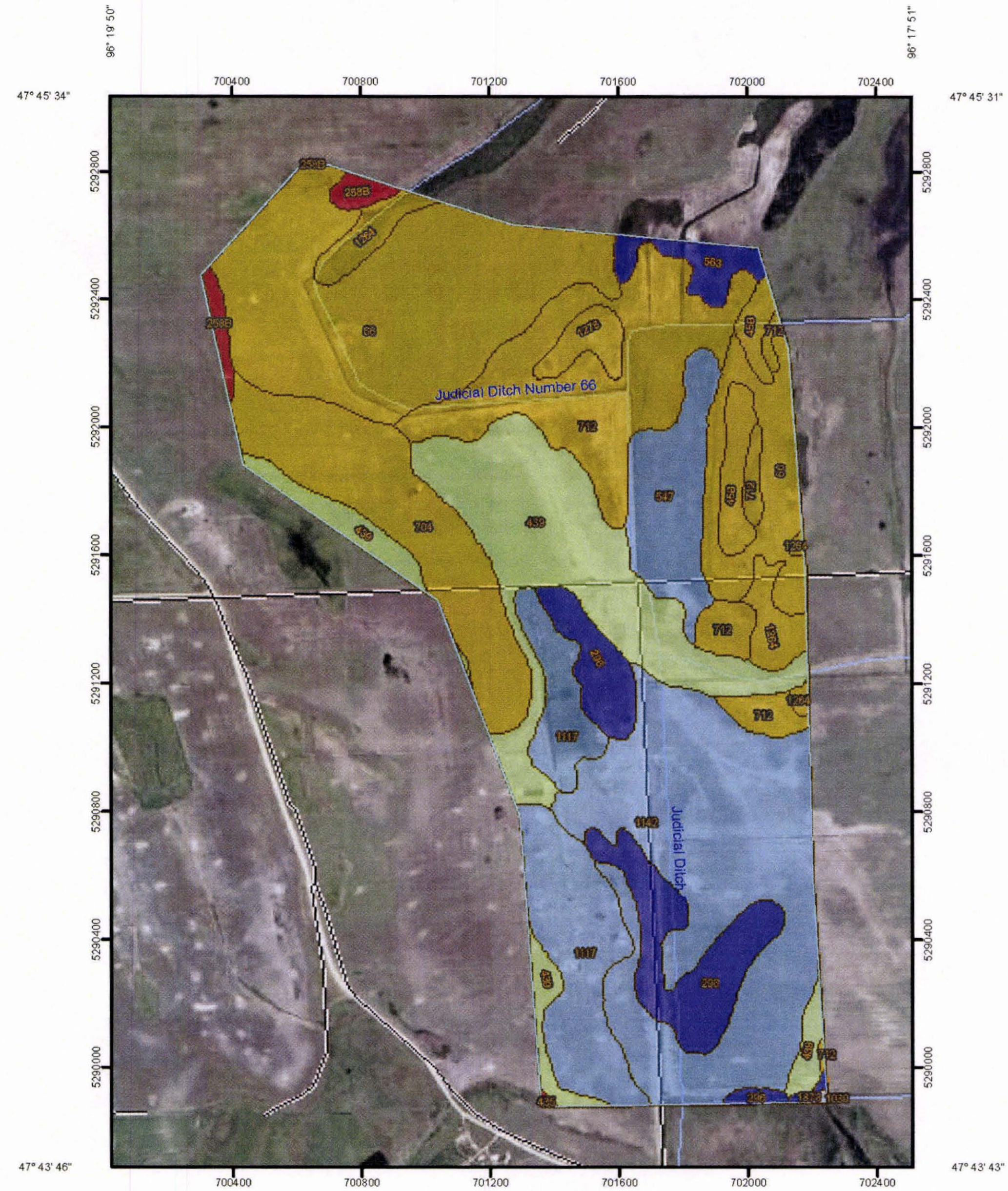
Rating Options

Aggregation Method: Dominant Condition

Component Percent Cutoff: *None Specified*

Tie-break Rule: Higher

Available Water Capacity—Polk County, Minnesota
(Judicial Ditch 66)



Map Scale: 1:16,000 if printed on A size (8.5" x 11") sheet.

Meters: 0, 150, 300, 600, 900

Feet: 0, 500, 1,000, 2,000, 3,000

N

MAP LEGEND

Area of Interest (AOI)

Area of Interest (AOI)

Soils

Soil Map Units

Soil Ratings

<= 0.06

> 0.06 AND <= 0.09

> 0.09 AND <= 0.14

> 0.14 AND <= 0.16

> 0.16 AND <= 0.21

Not rated or not available

Political Features

Cities

Water Features

Oceans

Streams and Canals

Transportation

Rails

Interstate Highways

US Routes

Major Roads

Local Roads

MAP INFORMATION

Map Scale: 1:16,000 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:20,000.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: UTM Zone 14N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Polk County, Minnesota
Survey Area Data: Version 6, Mar 25, 2009

Date(s) aerial images were photographed: 6/20/2003

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Available Water Capacity

Available Water Capacity— Summary by Map Unit — Polk County, Minnesota				
Map unit symbol	**Map unit name**	**Rating (centimeters per centimeter)**	**Acres in AOI**	**Percent of AOI**
45B	Maddock loamy fine sand, 1 to 6 percent slopes	0.09	16.3	1.9%
66	Flaming loamy fine sand	0.09	178.8	20.9%
258B	Sandberg loamy sand, 1 to 6 percent slopes	0.06	8.2	1.0%
296	Fram loam	0.18	54.2	6.3%
435	Syrene sandy loam	0.06	0.4	0.0%
439	Strathcona fine sandy loam	0.14	119.7	14.0%
547	Deerwood muck	0.16	37.5	4.4%
563	Northwood muck	0.18	11.5	1.3%
704	Wyrene sandy loam	0.09	72.9	8.5%
712	Rosewood fine sandy loam	0.08	100.5	11.8%
1030	Pits, gravel-udipsamments complex		0.3	0.0%
1117	Hedman loam	0.16	69.2	8.1%
1142	Hedman-Fram complex	0.16	154.2	18.0%
1264	Ulen loamy fine sand	0.08	21.6	2.5%
1278	Rosewood-Venlo complex	0.08	9.0	1.1%
1878	Hamre muck	0.21	1.1	0.1%
Totals for Area of Interest			**855.4**	**100.0%**

Description

Available water capacity (AWC) refers to the quantity of water that the soil is capable of storing for use by plants. The capacity for water storage is given in centimeters of water per centimeter of soil for each soil layer. The capacity varies, depending on soil properties that affect retention of water. The most important properties are the content of organic matter, soil texture, bulk density, and soil structure, with corrections for salinity and rock fragments. Available water capacity is an important factor in the choice of plants or crops to be grown and in the design and management of irrigation systems. It is not an estimate of the quantity of water actually available to plants at any given time.

Available water supply (AWS) is computed as AWC times the thickness of the soil. For example, if AWC is 0.15 cm/cm, the available water supply for 25 centimeters of soil would be 0.15 x 25, or 3.75 centimeters of water.

For each soil layer, AWC is recorded as three separate values in the database. A low value and a high value indicate the range of this attribute for the soil component. A "representative" value indicates the expected value of this attribute for the component. For this soil property, only the representative value is used.

Rating Options

Units of Measure: centimeters per centimeter

Aggregation Method: Dominant Component

Component Percent Cutoff: *None Specified*

Tie-break Rule: Higher

Interpret Nulls as Zero: No

Layer Options: Depth Range

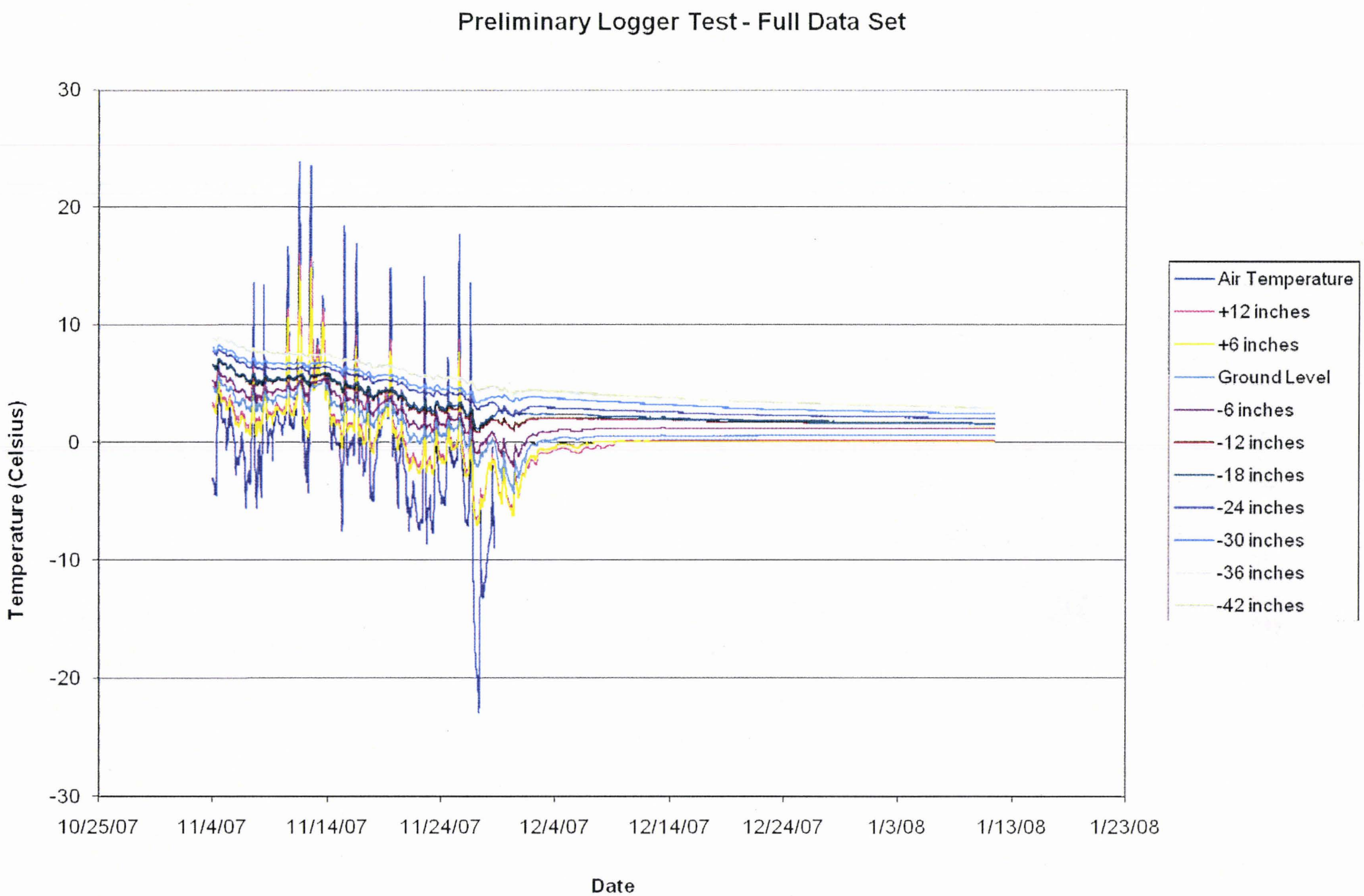
Top Depth: 1

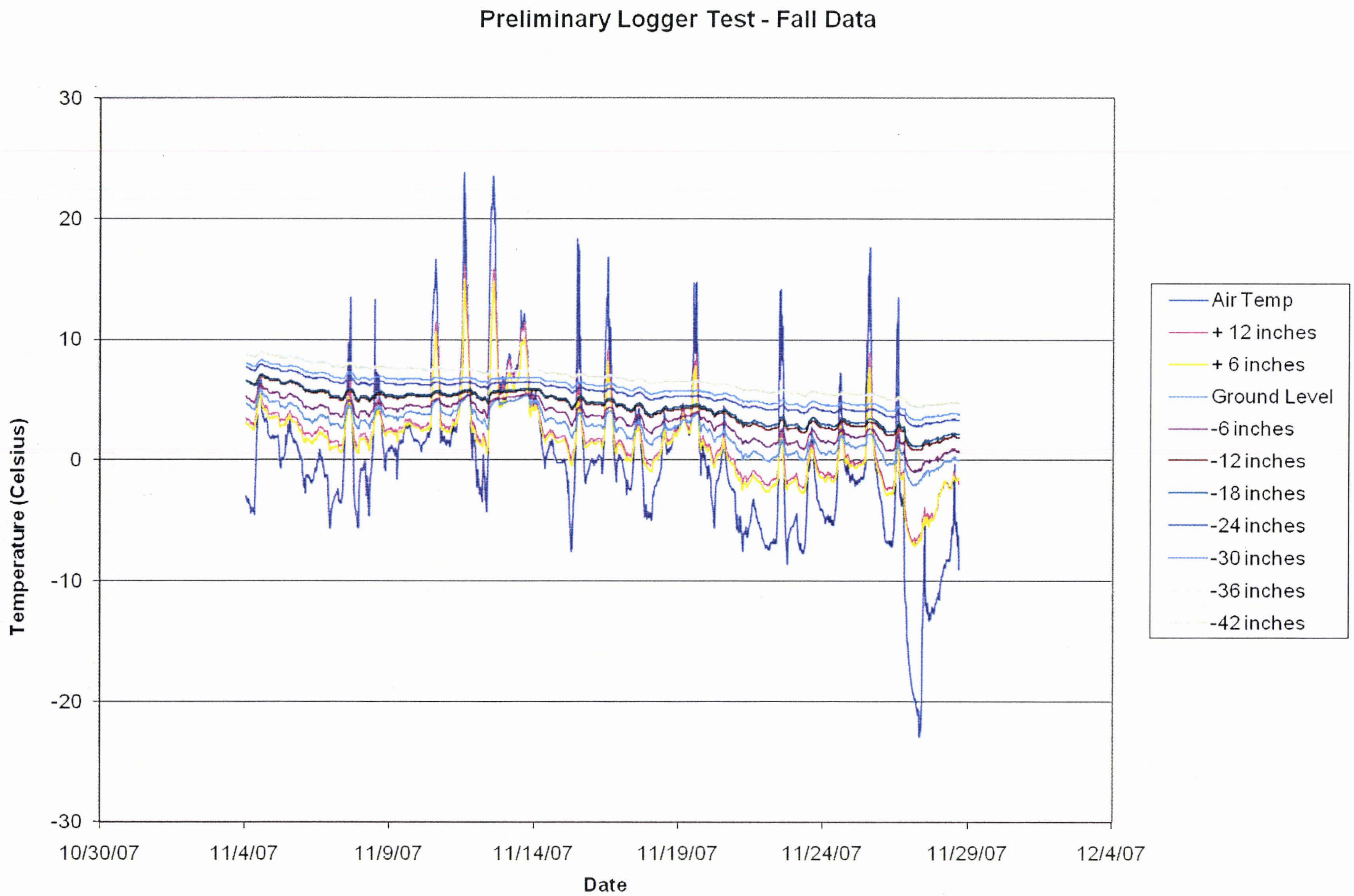
Bottom Depth: 60

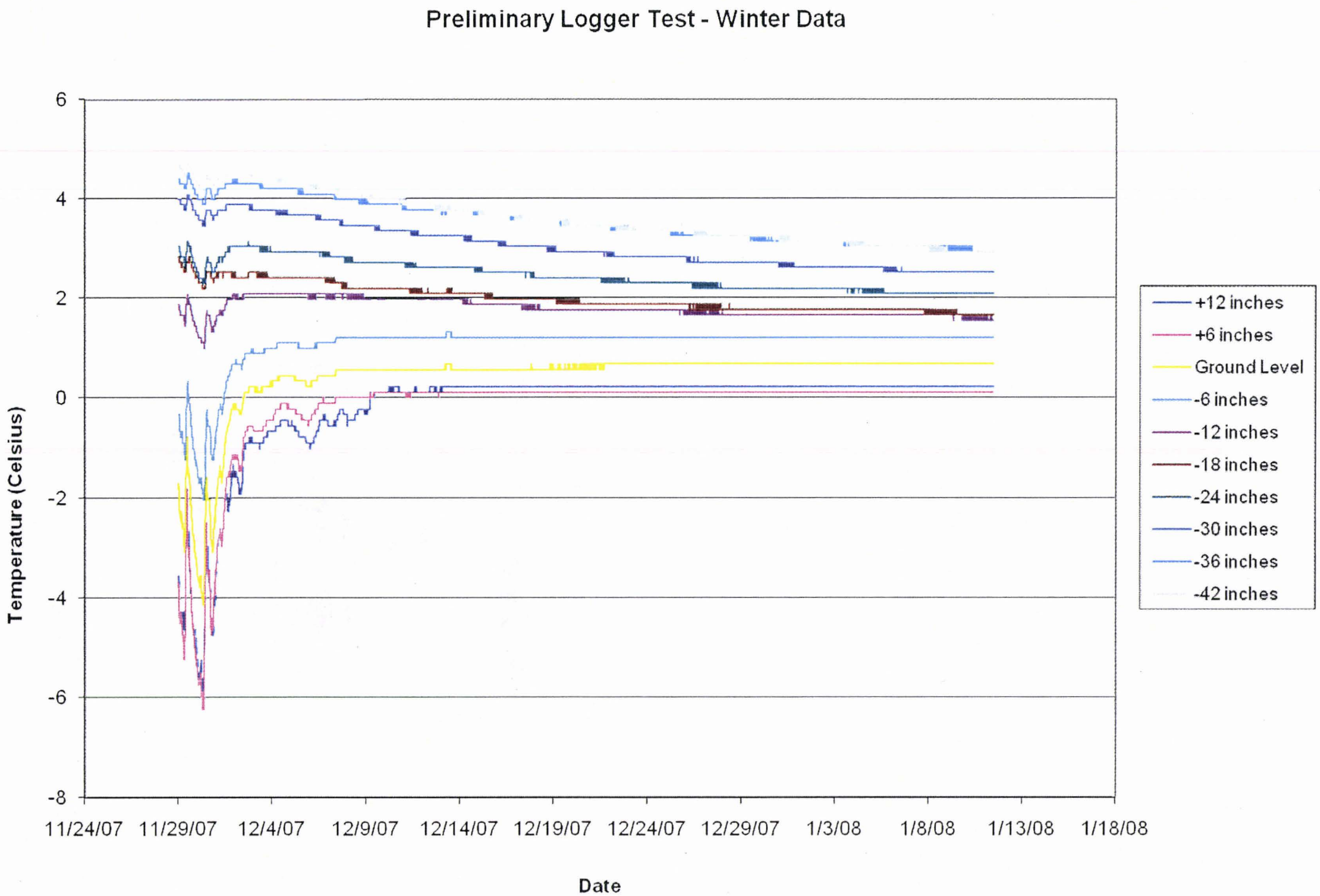
Units of Measure: Inches

Appendix B

Preliminary Logger Testing Data


Preliminary Logger Test - Full Data Set
30
20
10
0
-10
-20
-30
Temperature (Celsius)
10/25/07
11/4/07
11/14/07
11/24/07
12/4/07
12/14/07
12/24/07
1/3/08
1/13/08
1/23/08
Date
Air Temperature
+12 inches
+6 inches
Ground Level
-6 inches
-12 inches
-18 inches
-24 inches
-30 inches
-36 inches
-42 inches


Preliminary Logger Test - Fall Data
Temperature (Celsius)
30
20
10
0
-10
-20
-30
10/30/07
11/4/07
11/9/07
11/14/07
11/19/07
11/24/07
11/29/07
12/4/07
Date
Air Temp
+ 12 inches
+ 6 inches
Ground Level
-6 inches
-12 inches
-18 inches
-24 inches
-30 inches
-36 inches
-42 inches


Preliminary Logger Test - Winter Data
Temperature (Celsius)
6
4
2
0
-2
-4
-6
-8
11/24/07
11/29/07
12/4/07
12/9/07
12/14/07
12/19/07
12/24/07
12/29/07
1/3/08
1/8/08
1/13/08
1/18/08
Date
+12 inches
+6 inches
Ground Level
-6 inches
-12 inches
-18 inches
-24 inches
-30 inches
-36 inches
-42 inches

Appendix C

R Stats Data Output

All Data G1 – G2 Analysis

R version 2.10.1 (2009-12-14)
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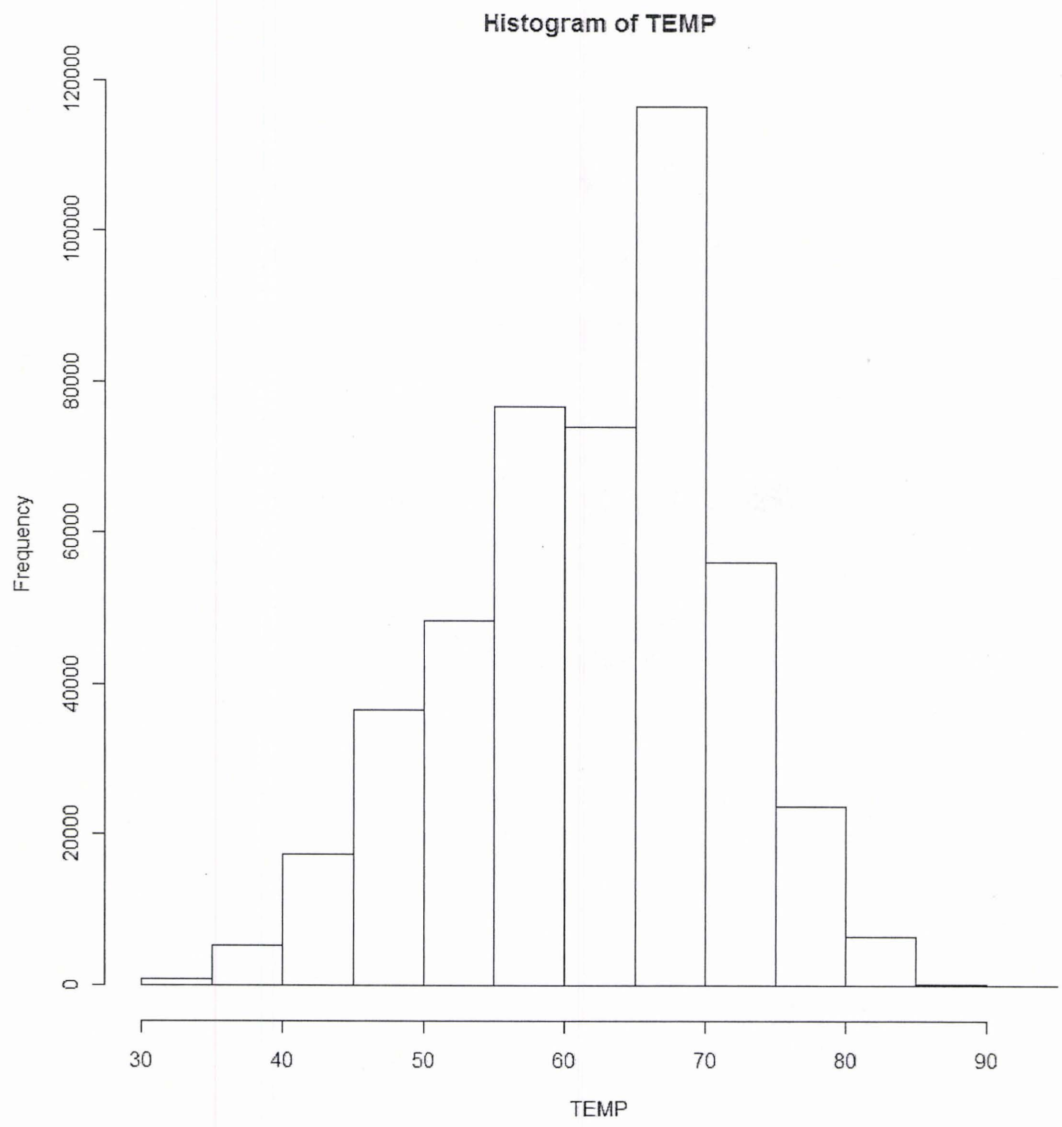
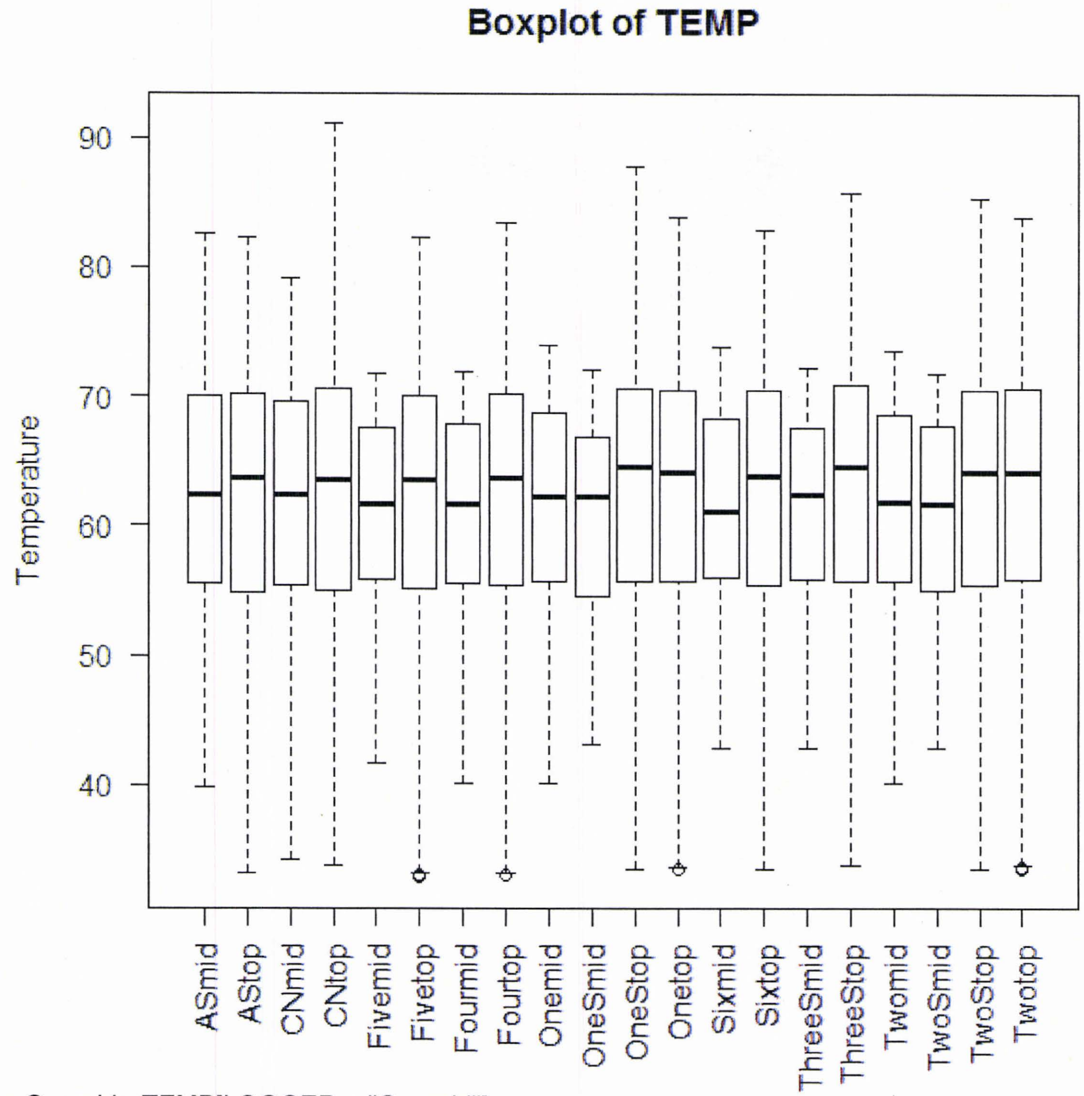
ISBN 3-900051-07-0

ANOVA Analysis

```
> work <- read.csv("ALL_TOPMID.txt")
> attach(work)
> hist(TEMP)
```



```
> boxplot(TEMP ~ LOGGER,main="Boxplot of TEMP", ylab="Temperature",las=2)
```




```
> Onemid<-TEMP[LOGGER=="Onemid"]
> Onetop<-TEMP[LOGGER=="Onetop"]
> Twomid<-TEMP[LOGGER=="Twomid"]
> Twotop<-TEMP[LOGGER=="Twotop"]
> Fourmid<-TEMP[LOGGER=="Fourmid"]
> Fourtop<-TEMP[LOGGER=="Fourtop"]
> Fivemid<-TEMP[LOGGER=="Fivemid"]
> Fivetop<-TEMP[LOGGER=="Fivetop"]
> Sixmid<-TEMP[LOGGER=="Sixmid"]
> Sixtop<-TEMP[LOGGER=="Sixtop"]
> OneSmid<-TEMP[LOGGER=="OneSmid"]
> OneStop<-TEMP[LOGGER=="OneStop"]
> TwoSmid<-TEMP[LOGGER=="TwoSmid"]
> TwoStop<-TEMP[LOGGER=="TwoStop"]
```

```
> ThreeSmid<-TEMP[LOGGER=="ThreeSmid"]
> ThreeStop<-TEMP[LOGGER=="ThreeStop"]
> ASmid<-TEMP[LOGGER=="ASmid"]
> AStop<-TEMP[LOGGER=="AStop"]
> CNmid<-TEMP[LOGGER=="CNmid"]
> CNtop<-TEMP[LOGGER=="CNtop"]
> var(Onemid); var(Onetop); var(Twomid); var(Twotop); var(Fourmid); var(Fourtop); var(Fivemid);
var(Fivetop); var(Sixmid); var(Sixtop); var(OneSmid); var(OneStop); var(TwoSmid);
var(TwoStop); var(ThreeSmid); var(ThreeStop); var(ASmid); var(AStop); var(CNmid); var(CNtop)
[1] 68.90044
[1] 112.0979
[1] 69.85584
[1] 111.9174
[1] 62.47089
[1] 111.3400
[1] 56.33274
[1] 108.8999
[1] 57.0245
[1] 109.9005
[1] 52.76899
[1] 115.9882
[1] 57.05173
[1] 114.2121
[1] 52.67116
[1] 114.3664
[1] 89.63989
[1] 110.0912
[1] 94.51068
[1] 113.1499
>
>
> TEMP <- aov(TEMP~LOGGER)
> summary(TEMP)
             Df   Sum Sq Mean Sq F value    Pr(>F)
LOGGER        19   347931 18312.2  205.39 < 2.2e-16 ***
Residuals   462400 41227362    89.2
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Tukey's Analysis

```
> TEMP.mcp <- TukeyHSD(TEMP, "LOGGER")
> TEMP.mcp
  Tukey multiple comparisons of means
    95% family-wise confidence level

Fit: aov(formula = TEMP ~ LOGGER)
```

Logger	diff	lwr	upr	p
AStop-ASmid	-0.27915306	-0.59037102	0.032064893	0.1479043
CNmid-ASmid	-0.82127123	-1.13248918	-0.510053268	0
CNtop-ASmid	0.01194036	-0.2992776	0.323158315	1
Fivemid-ASmid	-1.46776061	-1.77897856	-1.15654265	0
Fivetop-ASmid	-0.19228502	-0.50350298	0.118932935	0.8073004

Fourmid-ASmid	-1.69507629	-2.00629425	-1.383858337	0
Fourtop-ASmid	0.06042481	-0.25079315	0.371642766	1
Onemid-ASmid	-0.93658172	-1.24779968	-0.625363765	0
OneSmid-ASmid	-2.05075658	-2.36197454	-1.739538628	0
OneStop-ASmid	0.67240932	0.36119137	0.983627282	0
Onetop-ASmid	0.44668033	0.13546238	0.757898291	0.0000667
Sixmid-ASmid	-1.17696393	-1.48818189	-0.865745972	0
Sixtop-ASmid	0.17672648	-0.13449147	0.48794444	0.8981455
ThreeSmid-ASmid	-1.02633074	-1.3375487	-0.715112781	0
ThreeStop-ASmid	0.78099057	0.46977261	1.092208529	0
Twomid-ASmid	-1.30628571	-1.61750367	-0.995067757	0
TwoSmid-ASmid	-1.61810514	-1.9293231	-1.306887185	0
TwoStop-ASmid	0.46833117	0.15711321	0.779549128	0.0000179
Twotop-ASmid	0.54393465	0.23271669	0.855152606	0.0000001
CNmid-AStop	-0.54211816	-0.85333612	-0.230900204	0.0000001
CNtop-AStop	0.29109342	-0.02012454	0.602311379	0.1013399
Fivemid-AStop	-1.18860754	-1.4998255	-0.877389586	0
Fivetop-AStop	0.08686804	-0.22434992	0.398085999	0.9999868
Fourmid-AStop	-1.41592323	-1.72714119	-1.104705273	0
Fourtop-AStop	0.33957787	0.02835992	0.65079583	0.0161256
Onemid-AStop	-0.65742866	-0.96864662	-0.346210701	0
OneSmid-AStop	-1.77160352	-2.08282148	-1.460385563	0
OneStop-AStop	0.95156239	0.64034443	1.262780347	0
Onetop-AStop	0.7258334	0.41461544	1.037051356	0
Sixmid-AStop	-0.89781086	-1.20902882	-0.586592907	0
Sixtop-AStop	0.45587955	0.14466159	0.767097504	0.0000385
ThreeSmid-AStop	-0.74717767	-1.05839563	-0.435959717	0
ThreeStop-AStop	1.06014364	0.74892568	1.371361593	0
Twomid-AStop	-1.02713265	-1.33835061	-0.715914693	0
TwoSmid-AStop	-1.33895208	-1.65017004	-1.027734121	0
TwoStop-AStop	0.74748424	0.43626628	1.058702193	0
Twotop-AStop	0.82308771	0.51186976	1.13430567	0
CNtop-CNmid	0.83321158	0.52199363	1.14442954	0
Fivemid-CNmid	-0.64648938	-0.95770734	-0.335271425	0
Fivetop-CNmid	0.6289862	0.31776825	0.94020416	0
Fourmid-CNmid	-0.87380507	-1.18502303	-0.562587112	0
Fourtop-CNmid	0.88169603	0.57047808	1.192913991	0
Onemid-CNmid	-0.1153105	-0.42652845	0.195907461	0.9991276
OneSmid-CNmid	-1.22948536	-1.54070332	-0.918267402	0
OneStop-CNmid	1.49368055	1.18246259	1.804898508	0
Onetop-CNmid	1.26795156	0.9567336	1.579169517	0
Sixmid-CNmid	-0.3556927	-0.66691066	-0.044474746	0.0079406
Sixtop-CNmid	0.99799771	0.68677975	1.309215665	0
ThreeSmid-CNmid	-0.20505951	-0.51627747	0.106158444	0.709901

ThreeStop-CNmid	1.6022618	1.29104384	1.913479754	0
Twomid-CNmid	-0.48501449	-0.79623245	-0.173796532	0.0000062
TwoSmid-CNmid	-0.79683392	-1.10805187	-0.48561596	0
TwoStop-CNmid	1.2896024	0.97838444	1.600820354	0
Twotop-CNmid	1.36520587	1.05398792	1.676423831	0
Fivemid-CNtop	-1.47970096	-1.79091892	-1.168483007	0
Fivetop-CNtop	-0.20422538	-0.51544334	0.106992578	0.71676
Fourmid-CNtop	-1.70701665	-2.01823461	-1.395798694	0
Fourtop-CNtop	0.04848445	-0.26273351	0.359702409	1
Onemid-CNtop	-0.94852208	-1.25974004	-0.637304122	0
OneSmid-CNtop	-2.06269694	-2.3739149	-1.751478985	0
OneStop-CNtop	0.66046897	0.34925101	0.971686925	0
Onetop-CNtop	0.43473998	0.12352202	0.745957934	0.000134
Sixmid-CNtop	-1.18890429	-1.50012224	-0.877686329	0
Sixtop-CNtop	0.16478613	-0.14643183	0.476004083	0.9448042
ThreeSmid-CNtop	-1.0382711	-1.34948905	-0.727053138	0
ThreeStop-CNtop	0.76905021	0.45783226	1.080268172	0
Twomid-CNtop	-1.31822607	-1.62944403	-1.007008114	0
TwoSmid-CNtop	-1.6300455	-1.94126346	-1.318827542	0
TwoStop-CNtop	0.45639081	0.14517286	0.767608771	0.0000373
Twotop-CNtop	0.53199429	0.22077633	0.843212248	0.0000003
Fivetop-Fivemid	1.27547558	0.96425763	1.586693542	0
Fourmid-Fivemid	-0.22731569	-0.53853364	0.08390227	0.5140616
Fourtop-Fivemid	1.52818542	1.21696746	1.839403373	0
Onemid-Fivemid	0.53117888	0.21996093	0.842396842	0.0000003
OneSmid-Fivemid	-0.58299598	-0.89421394	-0.27177802	0
OneStop-Fivemid	2.14016993	1.82895197	2.45138789	0
Onetop-Fivemid	1.91444094	1.60322298	2.225658899	0
Sixmid-Fivemid	0.29079668	-0.02042128	0.602014636	0.1023356
Sixtop-Fivemid	1.64448709	1.33326913	1.955705047	0
ThreeSmid-Fivemid	0.44142987	0.13021191	0.752647826	0.0000909
ThreeStop-Fivemid	2.24875118	1.93753322	2.559969136	0
Twomid-Fivemid	0.16147489	-0.14974306	0.47269285	0.9544227
TwoSmid-Fivemid	-0.15034454	-0.46156249	0.160873422	0.9778247
TwoStop-Fivemid	1.93609178	1.62487382	2.247309735	0
Twotop-Fivemid	2.01169526	1.7004773	2.322913213	0
Fourmid-Fivetop	-1.50279127	-1.81400923	-1.191573315	0
Fourtop-Fivetop	0.25270983	-0.05850813	0.563927788	0.3036904
Onemid-Fivetop	-0.7442967	-1.05551466	-0.433078743	0
OneSmid-Fivetop	-1.85847156	-2.16968952	-1.547253605	0
OneStop-Fivetop	0.86469435	0.55347639	1.175912305	0
Onetop-Fivetop	0.63896536	0.3277474	0.950183314	0
Sixmid-Fivetop	-0.98467891	-1.29589686	-0.673460949	0
Sixtop-Fivetop	0.3690115	0.05779355	0.680229462	0.0042757

ThreeSmid-Fivetop	-0.83404572	-1.14526367	-0.522827759	0
ThreeStop-Fivetop	0.97327559	0.66205764	1.284493551	0
Twomid-Fivetop	-1.11400069	-1.42521865	-0.802782735	0
TwoSmid-Fivetop	-1.42582012	-1.73703808	-1.114602163	0
TwoStop-Fivetop	0.66061619	0.34939824	0.971834151	0
Twotop-Fivetop	0.73621967	0.42500171	1.047437628	0
Fourtop-Fourmid	1.7555011	1.44428315	2.06671906	0
Onemid-Fourmid	0.75849457	0.44727661	1.069712529	0
OneSmid-Fourmid	-0.35568029	-0.66689825	-0.044462333	0.007945
OneStop-Fourmid	2.36748562	2.05626766	2.678703577	0
Onetop-Fourmid	2.14175663	1.83053867	2.452974586	0
Sixmid-Fourmid	0.51811237	0.20689441	0.829330323	0.0000007
Sixtop-Fourmid	1.87180278	1.56058482	2.183020734	0
ThreeSmid-Fourmid	0.66874556	0.3575276	0.979963513	0
ThreeStop-Fourmid	2.47606687	2.16484891	2.787284823	0
Twomid-Fourmid	0.38879058	0.07757262	0.700008537	0.0016166
TwoSmid-Fourmid	0.07697115	-0.23424681	0.388189109	0.9999981
TwoStop-Fourmid	2.16340747	1.85218951	2.474625423	0
Twotop-Fourmid	2.23901094	1.92779299	2.5502289	0
Onemid-Fourtop	-0.99700653	-1.30822449	-0.685788574	0
OneSmid-Fourtop	-2.11118139	-2.42239935	-1.799963436	0
OneStop-Fourtop	0.61198452	0.30076656	0.923202474	0
Onetop-Fourtop	0.38625553	0.07503757	0.697473483	0.0018376
Sixmid-Fourtop	-1.23738874	-1.54860669	-0.92617078	0
Sixtop-Fourtop	0.11630167	-0.19491628	0.427519631	0.9990199
ThreeSmid-Fourtop	-1.08675555	-1.3979735	-0.77553759	0
ThreeStop-Fourtop	0.72056576	0.40934781	1.03178372	0
Twomid-Fourtop	-1.36671052	-1.67792848	-1.055492566	0
TwoSmid-Fourtop	-1.67852995	-1.98974791	-1.367311994	0
TwoStop-Fourtop	0.40790636	0.0966884	0.71912432	0.000596
Twotop-Fourtop	0.48350984	0.17229188	0.794727797	0.0000069
OneSmid-Onemid	-1.11417486	-1.42539282	-0.802956905	0
OneStop-Onemid	1.60899105	1.29777309	1.920209005	0
Onetop-Onemid	1.38326206	1.0720441	1.694480014	0
Sixmid-Onemid	-0.24038221	-0.55160016	0.070835751	0.400365
Sixtop-Onemid	1.1133082	0.80209025	1.424526162	0
ThreeSmid-Onemid	-0.08974902	-0.40096697	0.221468941	0.999978
ThreeStop-Onemid	1.71757229	1.40635434	2.028790251	0
Twomid-Onemid	-0.36970399	-0.68092195	-0.058486035	0.004137
TwoSmid-Onemid	-0.68152342	-0.99274138	-0.370305463	0
TwoStop-Onemid	1.40491289	1.09369494	1.71613085	0
Twotop-Onemid	1.48051637	1.16929841	1.791734328	0
OneStop-OneSmid	2.72316591	2.41194795	3.034383867	0
Onetop-OneSmid	2.49743692	2.18621896	2.808654876	0

Sixmid-OneSmid	0.87379266	0.5625747	1.185010613	0
Sixtop-OneSmid	2.22748307	1.91626511	2.538701025	0
ThreeSmid-OneSmid	1.02442585	0.71320789	1.335643804	0
ThreeStop-OneSmid	2.83174716	2.5205292	3.142965114	0
Twomid-OneSmid	0.74447087	0.43325291	1.055688828	0
TwoSmid-OneSmid	0.43265144	0.12143349	0.7438694	0.0001511
TwoStop-OneSmid	2.51908776	2.2078698	2.830305713	0
Twotop-OneSmid	2.59469123	2.28347328	2.905909191	0
Onetop-OneStop	-0.22572899	-0.53694695	0.085488966	0.52829
Sixmid-OneStop	-1.84937325	-2.16059121	-1.538155296	0
Sixtop-OneStop	-0.49568284	-0.8069008	-0.184464885	0.0000031
ThreeSmid-OneStop	-1.69874006	-2.00995802	-1.387522106	0
ThreeStop-OneStop	0.10858125	-0.20263671	0.419799204	0.999622
Twomid-OneStop	-1.97869504	-2.289913	-1.667477082	0
TwoSmid-OneStop	-2.29051447	-2.60173242	-1.97929651	0
TwoStop-OneStop	-0.20407815	-0.51529611	0.107139803	0.7179645
Twotop-OneStop	-0.12847468	-0.43969263	0.182743281	0.9964088
Sixmid-Onetop	-1.62364426	-1.93486222	-1.312426305	0
Sixtop-Onetop	-0.26995385	-0.58117181	0.041264106	0.1935975
ThreeSmid-Onetop	-1.47301107	-1.78422903	-1.161793115	0
ThreeStop-Onetop	0.33431024	0.02309228	0.645528195	0.0201253
Twomid-Onetop	-1.75296605	-2.06418401	-1.441748091	0
TwoSmid-Onetop	-2.06478548	-2.37600343	-1.753567519	0
TwoStop-Onetop	0.02165084	-0.28956712	0.332868794	1
Twotop-Onetop	0.09725431	-0.21396364	0.408472272	0.9999246
Sixtop-Sixmid	1.35369041	1.04247245	1.664908369	0
ThreeSmid-Sixmid	0.15063319	-0.16058477	0.461851148	0.9773706
ThreeStop-Sixmid	1.9579545	1.64673654	2.269172458	0
Twomid-Sixmid	-0.12932179	-0.44053974	0.181896172	0.9961018
TwoSmid-Sixmid	-0.44114121	-0.75235917	-0.129923256	0.0000924
TwoStop-Sixmid	1.6452951	1.33407714	1.956513057	0
Twotop-Sixmid	1.72089858	1.40968062	2.032116535	0
ThreeSmid-Sixtop	-1.20305722	-1.51427518	-0.891839263	0
ThreeStop-Sixtop	0.60426409	0.29304613	0.915482046	0
Twomid-Sixtop	-1.4830122	-1.79423015	-1.171794239	0
TwoSmid-Sixtop	-1.79483162	-2.10604958	-1.483613668	0
TwoStop-Sixtop	0.29160469	-0.01961327	0.602822646	0.0996426
Twotop-Sixtop	0.36720817	0.05599021	0.678426123	0.0046576
ThreeStop-ThreeSmid	1.80732131	1.49610335	2.118539267	0
Twomid-ThreeSmid	-0.27995498	-0.59117293	0.031262981	0.1443402
TwoSmid-ThreeSmid	-0.5917744	-0.90299236	-0.280556447	0
TwoStop-ThreeSmid	1.49466191	1.18344395	1.805879867	0
Twotop-ThreeSmid	1.57026539	1.25904743	1.881483344	0
Twomid-ThreeStop	-2.08727629	-2.39849424	-1.776058328	0

TwoSmid-ThreeStop	-2.39909571	-2.71031367	-2.087877756	0
TwoStop-ThreeStop	-0.3126594	-0.62387736	-0.001441443	0.0473818
Twotop-ThreeStop	-0.23705592	-0.54827388	0.074162034	0.4284806
TwoSmid-Twomid	-0.31181943	-0.62303739	-0.000601471	0.0488928
TwoStop-Twomid	1.77461689	1.46339893	2.085834843	0
Twotop-Twomid	1.85022036	1.53900241	2.16143832	0
TwoStop-TwoSmid	2.08643631	1.77521836	2.397654271	0
Twotop-TwoSmid	2.16203979	1.85082183	2.473257748	0
Twotop-TwoStop	0.07560348	-0.23561448	0.386821435	0.9999986

```
> plot(TEMP.mcp)
```

All Data G2 – G3 Analysis

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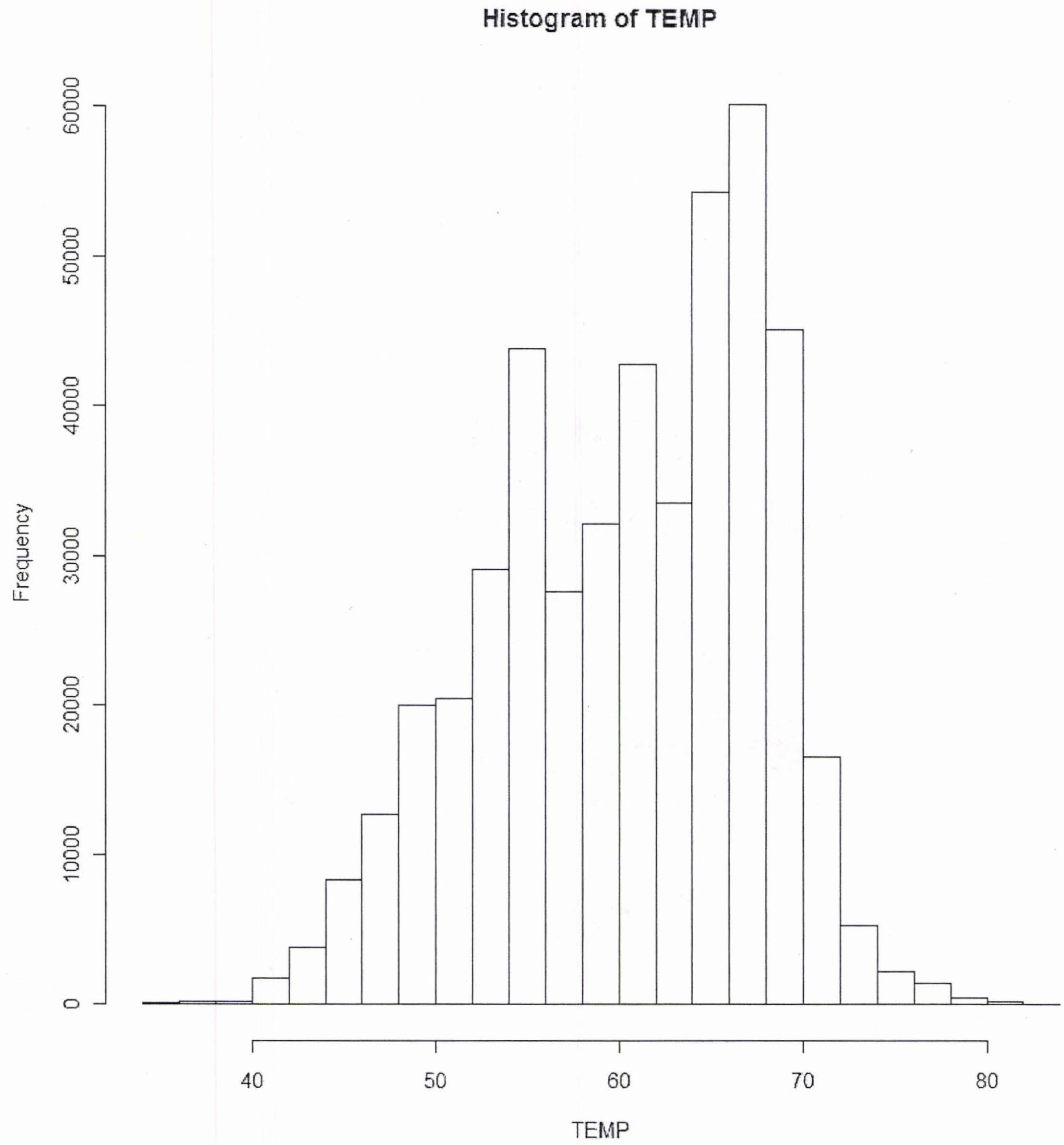
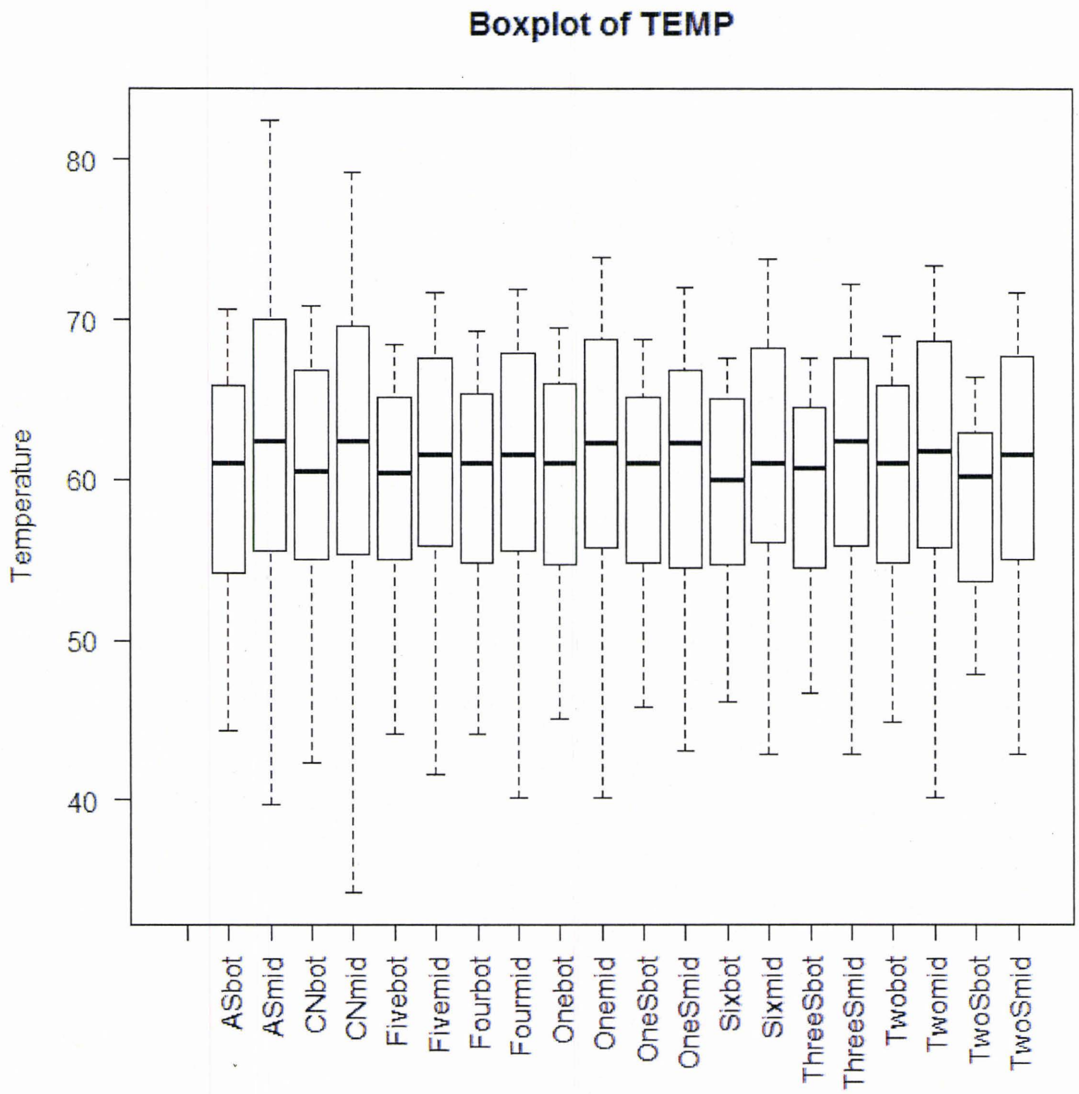
ANOVA Analysis

```
> work <- read.csv("ALL_BOTMID.txt")
> attach(work)
> hist(TEMP)
```



```
> boxplot(TEMP ~ LOGGER,main="Boxplot of TEMP", ylab="Temperature",las=2)
```




```
> Onebot<-TEMP[LOGGER=="Onebot"]
> Onemid<-TEMP[LOGGER=="Onemid"]
> Twobot<-TEMP[LOGGER=="Twobot"]
> Twomid<-TEMP[LOGGER=="Twomid"]
> Fourbot<-TEMP[LOGGER=="Fourbot"]
> Fourmid<-TEMP[LOGGER=="Fourmid"]
> Fivebot<-TEMP[LOGGER=="Fivebot"]
> Fivemid<-TEMP[LOGGER=="Fivemid"]
> Sixbot<-TEMP[LOGGER=="Sixbot"]
> Sixmid<-TEMP[LOGGER=="Sixmid"]
> OneSbot<-TEMP[LOGGER=="OneSbot"]
> OneSmid<-TEMP[LOGGER=="OneSmid"]
> TwoSbot<-TEMP[LOGGER=="TwoSbot"]
> TwoSmid<-TEMP[LOGGER=="TwoSmid"]
> ThreeSbot<-TEMP[LOGGER=="ThreeSbot"]
> ThreeSmid<-TEMP[LOGGER=="ThreeSmid"]
> ASbot<-TEMP[LOGGER=="ASbot"]
```

```
> ASmid<-TEMP[LOGGER=="ASmid"]
> CNbot<-TEMP[LOGGER=="CNbot"]
> CNmid<-TEMP[LOGGER=="CNmid"]
> var(Onebot); var(Onemid); var(Twobot); var(Twomid); var(Fourbot); var(Fourmid);  var(Fivebot);
var(Fivemid);  var(Sixbot); var(Sixmid); var(OneSbot); var(OneSmid); var(TwoSbot);
var(TwoSmid); var(ThreeSbot); var(ThreeSmid); var(ASbot); var(ASmid); var(CNbot);
var(CNmid);
[1] 43.40971
[1] 68.90044
[1] 42.74777
[1] 69.85584
[1] 41.72585
[1] 62.47089
[1] 40.22482
[1] 56.33274
[1] 36.26472
[1] 57.0245
[1] 37.88197
[1] 52.76899
[1] 26.62396
[1] 57.05173
[1] 33.54149
[1] 52.67116
[1] 48.92699
[1] 89.63989
[1] 52.2611
[1] 94.51068
> TEMP <- aov(TEMP~LOGGER)
> summary(TEMP)
              Df   Sum Sq Mean Sq F value    Pr(>F)
LOGGER        19   341039 17949.4  337.13 < 2.2e-16 ***
Residuals   462400 24618990    53.2
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
231220 observations deleted due to missingness
```

<u>Tukey's Test</u>

```
> TEMP.mcp <- TukeyHSD(TEMP, "LOGGER")
> TEMP.mcp
  Tukey multiple comparisons of means
    95% family-wise confidence level

Fit: aov(formula = TEMP ~ LOGGER)
```

Logger	diff	lwr	upr	p
ASmid-ASbot	2.35606375	2.11556823	2.596559274	0
CNbot-ASbot	0.37825963	0.137764112	0.618755156	0.0000047
CNmid-ASbot	1.53479253	1.294297004	1.775288048	0
Fivebot-ASbot	-0.27135937	-0.511854892	-0.030863848	0.0097368
Fivemid-ASbot	0.88830314	0.647807622	1.128798666	0
Fourbot-ASbot	-0.16777877	-0.408274294	0.072716749	0.605632
Fourmid-ASbot	0.66098746	0.420491935	0.901482979	0

Onebot-ASbot	0.2002153	-0.04028022	0.440710824	0.2592624
Onemid-ASbot	1.41948203	1.178986507	1.659977551	0
OneSbot-ASbot	-0.11851006	-0.359005578	0.121985466	0.972712
OneSmid-ASbot	0.30530717	0.064811645	0.545802689	0.0011708
Sixbot-ASbot	-0.4588174	-0.699312917	-0.218321874	0
Sixmid-ASbot	1.17909982	0.938604301	1.419595345	0
ThreeSbot-ASbot	-0.48810605	-0.728601573	-0.247610529	0
ThreeSmid-ASbot	1.32973301	1.089237491	1.570228535	0
Twobot-ASbot	0.12595675	-0.114538773	0.366452271	0.9501685
Twomid-ASbot	1.04977804	0.809282515	1.290273559	0
TwoSbot-ASbot	-1.47100627	-1.711501793	-1.23051075	0
TwoSmid-ASbot	0.73795861	0.497463087	0.978454131	0
CNbot-ASmid	-1.97780412	-2.218299639	-1.737308596	0
CNmid-ASmid	-0.82127123	-1.061766747	-0.580775703	0
Fivebot-ASmid	-2.62742312	-2.867918644	-2.3869276	0
Fivemid-ASmid	-1.46776061	-1.708256129	-1.227265085	0
Fourbot-ASmid	-2.52384252	-2.764338046	-2.283347002	0
Fourmid-ASmid	-1.69507629	-1.935571816	-1.454580772	0
Onebot-ASmid	-2.15584845	-2.396343971	-1.915352928	0
Onemid-ASmid	-0.93658172	-1.177077244	-0.6960862	0
OneSbot-ASmid	-2.47457381	-2.715069329	-2.234078286	0
OneSmid-ASmid	-2.05075658	-2.291252107	-1.810261063	0
Sixbot-ASmid	-2.81488115	-3.055376669	-2.574385625	0
Sixmid-ASmid	-1.17696393	-1.417459451	-0.936468407	0
ThreeSbot-ASmid	-2.8441698	-3.084665324	-2.60367428	0
ThreeSmid-ASmid	-1.02633074	-1.26682626	-0.785835216	0
Twobot-ASmid	-2.230107	-2.470602524	-1.98961148	0
Twomid-ASmid	-1.30628571	-1.546781236	-1.065790192	0
TwoSbot-ASmid	-3.82707002	-4.067565545	-3.586574501	0
TwoSmid-ASmid	-1.61810514	-1.858600664	-1.377609621	0
CNmid-CNbot	1.15653289	0.91603737	1.397028414	0
Fivebot-CNbot	-0.649619	-0.890114526	-0.409123483	0
Fivemid-CNbot	0.51004351	0.269547988	0.750539032	0
Fourbot-CNbot	-0.54603841	-0.786533929	-0.305542885	0
Fourmid-CNbot	0.28272782	0.042232301	0.523223345	0.0049612
Onebot-CNbot	-0.17804433	-0.418539854	0.06245119	0.4865517
Onemid-CNbot	1.0412224	0.800726873	1.281717917	0
OneSbot-CNbot	-0.49676969	-0.737265212	-0.256274168	0
OneSmid-CNbot	-0.07295247	-0.313447989	0.167543055	0.9999519
Sixbot-CNbot	-0.83707703	-1.077572551	-0.596581508	0
Sixmid-CNbot	0.80084019	0.560344667	1.041335711	0

ThreeSbot-CNbot	-0.86636568	-1.106861207	-0.625870163	0
ThreeSmid-CNbot	0.95147338	0.710977857	1.191968901	0
Twobot-CNbot	-0.25230288	-0.492798407	-0.011807363	0.0276941
Twomid-CNbot	0.6715184	0.431022881	0.912013925	0
TwoSbot-CNbot	-1.84926591	-2.089761427	-1.608770384	0
TwoSmid-CNbot	0.35969897	0.119203453	0.600194497	0.0000214
Fivebot-CNmid	-1.8061519	-2.046647418	-1.565656375	0
Fivemid-CNmid	-0.64648938	-0.886984904	-0.40599386	0
Fourbot-CNmid	-1.7025713	-1.943066821	-1.462075777	0
Fourmid-CNmid	-0.87380507	-1.114300591	-0.633309547	0
Onebot-CNmid	-1.33457722	-1.575072746	-1.094081702	0
Onemid-CNmid	-0.1153105	-0.355806019	0.125185025	0.9795263
OneSbot-CNmid	-1.65330258	-1.893798104	-1.41280706	0
OneSmid-CNmid	-1.22948536	-1.469980882	-0.988989838	0
Sixbot-CNmid	-1.99360992	-2.234105444	-1.7531144	0
Sixmid-CNmid	-0.3556927	-0.596188226	-0.115197182	0.0000294
ThreeSbot-CNmid	-2.02289858	-2.263394099	-1.782403055	0
ThreeSmid-CNmid	-0.20505951	-0.445555035	0.035436009	0.2198056
Twobot-CNmid	-1.40883578	-1.649331299	-1.168340255	0
Twomid-CNmid	-0.48501449	-0.725510011	-0.244518967	0
TwoSbot-CNmid	-3.0057988	-3.24629432	-2.765303276	0
TwoSmid-CNmid	-0.79683392	-1.037329439	-0.556338395	0
Fivemid-Fivebot	1.15966251	0.919166993	1.400158037	0
Fourbot-Fivebot	0.1035806	-0.136914924	0.34407612	0.9939554
Fourmid-Fivebot	0.93234683	0.691851306	1.17284235	0
Onebot-Fivebot	0.47157467	0.23107915	0.712070194	0
Onemid-Fivebot	1.6908414	1.450345878	1.931336922	0
OneSbot-Fivebot	0.15284931	-0.087646207	0.393344836	0.7674316
OneSmid-Fivebot	0.57666654	0.336171015	0.817162059	0
Sixbot-Fivebot	-0.18745803	-0.427953547	0.053037497	0.382175
Sixmid-Fivebot	1.45045919	1.209963671	1.690954715	0
ThreeSbot-Fivebot	-0.21674668	-0.457242202	0.023748841	0.1420192
ThreeSmid-Fivebot	1.60109238	1.360596862	1.841587906	0
Twobot-Fivebot	0.39731612	0.156820598	0.637811641	0.0000009
Twomid-Fivebot	1.32113741	1.080641886	1.56163293	0
TwoSbot-Fivebot	-1.1996469	-1.440142423	-0.959151379	0
TwoSmid-Fivebot	1.00931798	0.768822457	1.249813501	0
Fourbot-Fivemid	-1.05608192	-1.296577439	-0.815586395	0
Fourmid-Fivemid	-0.22731569	-0.467811209	0.013179835	0.0914917
Onebot-Fivemid	-0.68808784	-0.928583364	-0.44759232	0
Onemid-Fivemid	0.53117888	0.290683363	0.771674407	0

OneSbot-Fivemid	-1.0068132	-1.247308722	-0.766317678	0
OneSmid-Fivemid	-0.58299598	-0.8234915	-0.342500456	0
Sixbot-Fivemid	-1.34712054	-1.587616062	-1.106625018	0
Sixmid-Fivemid	0.29079668	0.050301156	0.5312922	0.003008
ThreeSbot-Fivemid	-1.3764092	-1.616904717	-1.135913673	0
ThreeSmid-Fivemid	0.44142987	0.200934347	0.681925391	0
Twobot-Fivemid	-0.7623464	-1.002841917	-0.521850873	0
Twomid-Fivemid	0.16147489	-0.079020629	0.401970415	0.6771079
TwoSbot-Fivemid	-2.35930942	-2.599804938	-2.118813894	0
TwoSmid-Fivemid	-0.15034454	-0.390840057	0.090150987	0.7913142
Fourmid-Fourbot	0.82876623	0.588270708	1.069261752	0
Onebot-Fourbot	0.36799407	0.127498553	0.608489597	0.0000109
Onemid-Fourbot	1.5872608	1.34676528	1.827756324	0
OneSbot-Fourbot	0.04926872	-0.191226805	0.289764239	0.9999999
OneSmid-Fourbot	0.47308594	0.232590417	0.713581461	0
Sixbot-Fourbot	-0.29103862	-0.531534145	-0.050543101	0.0029624
Sixmid-Fourbot	1.3468786	1.106383073	1.587374117	0
ThreeSbot-Fourbot	-0.32032728	-0.5608228	-0.079831756	0.0004165
ThreeSmid-Fourbot	1.49751179	1.257016264	1.738007308	0
Twobot-Fourbot	0.29373552	0.05324	0.534231044	0.0024959
Twomid-Fourbot	1.21755681	0.977061288	1.458052332	0
TwoSbot-Fourbot	-1.3032275	-1.543723021	-1.062731977	0
TwoSmid-Fourbot	0.90573738	0.66524186	1.146232904	0
Onebot-Fourmid	-0.46077216	-0.701267677	-0.220276633	0
Onemid-Fourmid	0.75849457	0.51799905	0.998990094	0
OneSbot-Fourmid	-0.77949751	-1.019993035	-0.539001991	0
OneSmid-Fourmid	-0.35568029	-0.596175813	-0.115184769	0.0000294
Sixbot-Fourmid	-1.11980485	-1.360300375	-0.879309331	0
Sixmid-Fourmid	0.51811237	0.277616843	0.758607887	0
ThreeSbot-Fourmid	-1.14909351	-1.38958903	-0.908597986	0
ThreeSmid-Fourmid	0.66874556	0.428250034	0.909241078	0
Twobot-Fourmid	-0.53503071	-0.77552623	-0.294535186	0
Twomid-Fourmid	0.38879058	0.148295058	0.629286102	0.0000019
TwoSbot-Fourmid	-2.13199373	-2.372489251	-1.891498207	0
TwoSmid-Fourmid	0.07697115	-0.16352437	0.317466674	0.9998921
Onemid-Onebot	1.21926673	0.978771205	1.459762249	0
OneSbot-Onebot	-0.31872536	-0.55922088	-0.078229836	0.0004662
OneSmid-Onebot	0.10509186	-0.135403657	0.345587386	0.9928134
Sixbot-Onebot	-0.6590327	-0.899528219	-0.418537176	0
Sixmid-Onebot	0.97888452	0.738388999	1.219380043	0
ThreeSbot-Onebot	-0.68832135	-0.928816875	-0.447825831	0

ThreeSmid-Onebot	1.12951771	0.889022189	1.370013233	0
Twobot-Onebot	-0.07425855	-0.314754075	0.166236969	0.999937
Twomid-Onebot	0.84956274	0.609067213	1.090058257	0
TwoSbot-Onebot	-1.67122157	-1.911717095	-1.430726052	0
TwoSmid-Onebot	0.53774331	0.297247785	0.778238829	0
OneSbot-Onemid	-1.53799209	-1.778487607	-1.297496563	0
OneSmid-Onemid	-1.11417486	-1.354670385	-0.873679341	0
Sixbot-Onemid	-1.87829942	-2.118794947	-1.637803903	0
Sixmid-Onemid	-0.24038221	-0.480877729	0.000113315	0.0502732
ThreeSbot-Onemid	-1.90758808	-2.148083602	-1.667092558	0
ThreeSmid-Onemid	-0.08974902	-0.330244538	0.150746506	0.9990381
Twobot-Onemid	-1.29352528	-1.534020802	-1.053029758	0
Twomid-Onemid	-0.36970399	-0.610199514	-0.12920847	0.0000095
TwoSbot-Onemid	-2.8904883	-3.130983823	-2.649992779	0
TwoSmid-Onemid	-0.68152342	-0.922018942	-0.441027898	0
OneSmid-OneSbot	0.42381722	0.183321701	0.664312744	0.0000001
Sixbot-OneSbot	-0.34030734	-0.580802862	-0.099811818	0.0000966
Sixmid-OneSbot	1.29760988	1.057114357	1.5381054	0
ThreeSbot-OneSbot	-0.36959599	-0.610091517	-0.129100473	0.0000096
ThreeSmid-OneSbot	1.44824307	1.207747547	1.688738591	0
Twobot-OneSbot	0.24446681	0.003971283	0.484962327	0.0411977
Twomid-OneSbot	1.16828809	0.927792571	1.408783615	0
TwoSbot-OneSbot	-1.35249622	-1.592991737	-1.112000694	0
TwoSmid-OneSbot	0.85646866	0.615973143	1.096964187	0
Sixbot-OneSmid	-0.76412456	-1.004620084	-0.52362904	0
Sixmid-OneSmid	0.87379266	0.633297134	1.114288178	0
ThreeSbot-OneSmid	-0.79341322	-1.033908739	-0.552917696	0
ThreeSmid-OneSmid	1.02442585	0.783930325	1.264921369	0
Twobot-OneSmid	-0.17935042	-0.419845939	0.061145105	0.4716135
Twomid-OneSmid	0.74447087	0.503975349	0.984966393	0
TwoSbot-OneSmid	-1.77631344	-2.01680896	-1.535817916	0
TwoSmid-OneSmid	0.43265144	0.192155921	0.673146964	0
Sixmid-Sixbot	1.63791722	1.397421696	1.87841274	0
ThreeSbot-Sixbot	-0.02928866	-0.269784177	0.211206867	1
ThreeSmid-Sixbot	1.78855041	1.548054887	2.029045931	0
Twobot-Sixbot	0.58477414	0.344278623	0.825269667	0
Twomid-Sixbot	1.50859543	1.268099911	1.749090955	0
TwoSbot-Sixbot	-1.01218888	-1.252684398	-0.771693354	0
TwoSmid-Sixbot	1.196776	0.956280483	1.437271526	0
ThreeSbot-Sixmid	-1.66720587	-1.907701395	-1.426710352	0
ThreeSmid-Sixmid	0.15063319	-0.089862331	0.391128713	0.7886246

Twobot-Sixmid	-1.05314307	-1.293638595	-0.812647552	0
Twomid-Sixmid	-0.12932179	-0.369817307	0.111173737	0.9364053
TwoSbot-Sixmid	-2.65010609	-2.890601616	-2.409610572	0
TwoSmid-Sixmid	-0.44114121	-0.681636736	-0.200645692	0
ThreeSmid-ThreeSbot	1.81783906	1.577343542	2.058334586	0
Twobot-ThreeSbot	0.6140628	0.373567278	0.854558322	0
Twomid-ThreeSbot	1.53788409	1.297388566	1.77837961	0
TwoSbot-ThreeSbot	-0.98290022	-1.223395742	-0.742404699	0
TwoSmid-ThreeSbot	1.22606466	0.985569138	1.466560182	0
Twobot-ThreeSmid	-1.20377626	-1.444271786	-0.963280742	0
Twomid-ThreeSmid	-0.27995498	-0.520450498	-0.039459454	0.0058677
TwoSbot-ThreeSmid	-2.80073928	-3.041234807	-2.560243763	0
TwoSmid-ThreeSmid	-0.5917744	-0.832269926	-0.351278882	0
Twomid-Twobot	0.92382129	0.683325766	1.16431681	0
TwoSbot-Twobot	-1.59696302	-1.837458543	-1.356467499	0
TwoSmid-Twobot	0.61200186	0.371506338	0.852497382	0
TwoSbot-Twomid	-2.52078431	-2.761279831	-2.280288787	0
TwoSmid-Twomid	-0.31181943	-0.55231495	-0.071323906	0.0007531
TwoSmid-TwoSbot	2.20896488	1.968469359	2.449460402	0

```
> plot(TEMP.mcp)
```

Summer Data G1 – G2 Analysis

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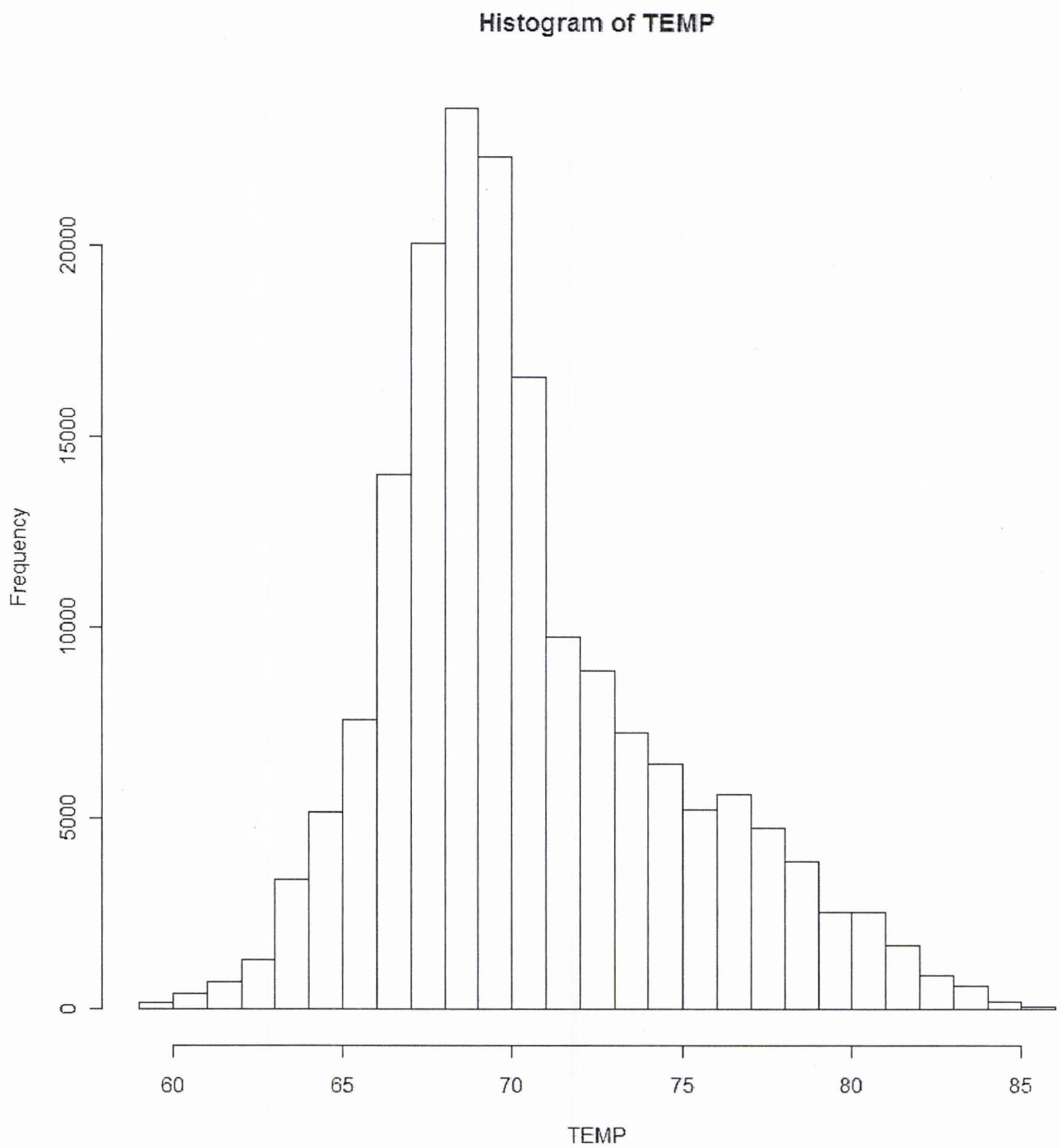
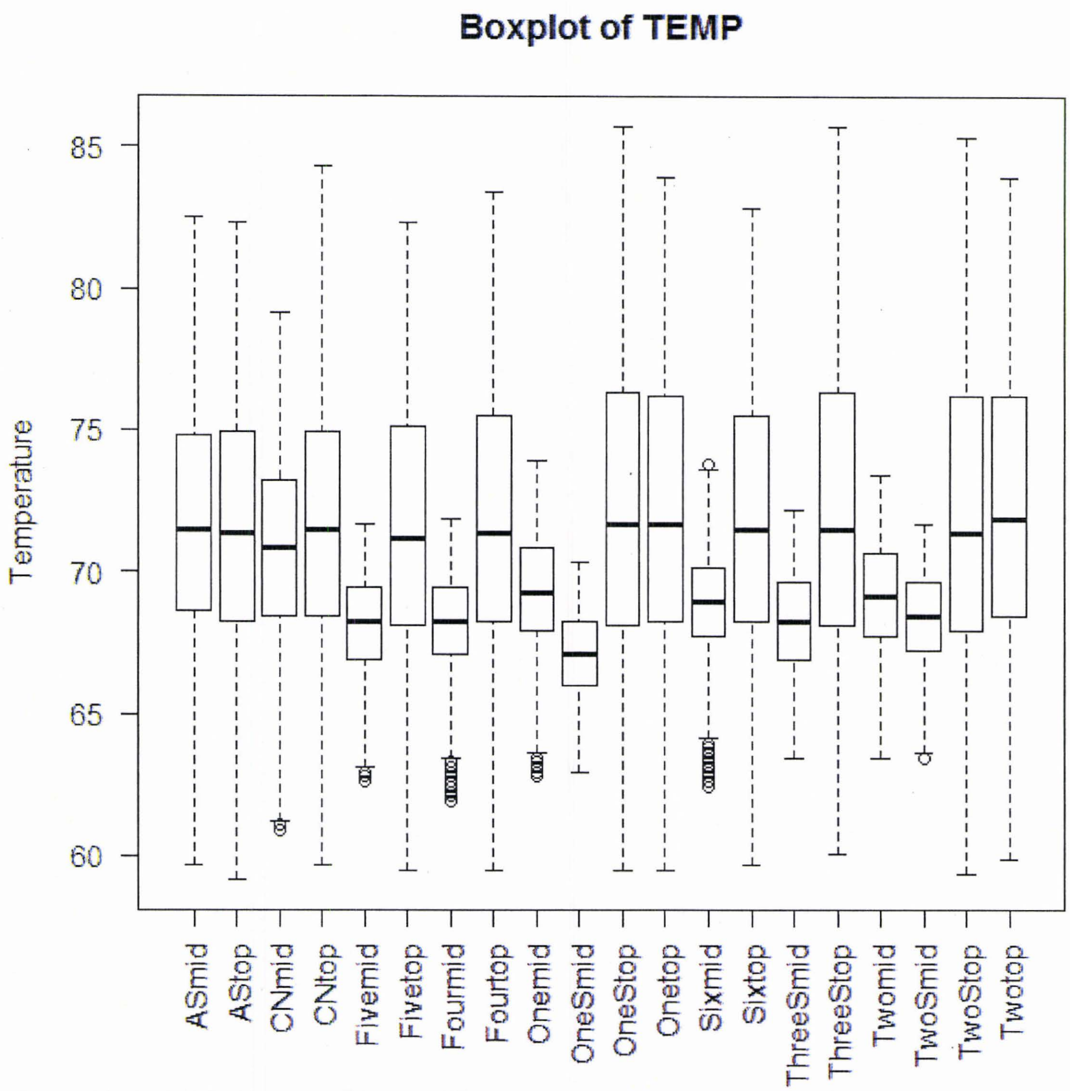
ANOVA Analysis

```
> work <- read.csv("SPRING_TOPMID.txt")
> attach(work)
> hist(TEMP)
```



```
> boxplot(TEMP ~ LOGGER,main="Boxplot of TEMP", ylab="Temperature",las=2)
```




```
> Onemid<-TEMP[LOGGER=="Onemid"]
> Onetop<-TEMP[LOGGER=="Onetop"]
> Twomid<-TEMP[LOGGER=="Twomid"]
> Twotop<-TEMP[LOGGER=="Twotop"]
> Fourmid<-TEMP[LOGGER=="Fourmid"]
> Fourtop<-TEMP[LOGGER=="Fourtop"]
> Fivemid<-TEMP[LOGGER=="Fivemid"]
> Fivetop<-TEMP[LOGGER=="Fivetop"]
> Sixmid<-TEMP[LOGGER=="Sixmid"]
> Sixtop<-TEMP[LOGGER=="Sixtop"]
> OneSmid<-TEMP[LOGGER=="OneSmid"]
> OneStop<-TEMP[LOGGER=="OneStop"]
> TwoSmid<-TEMP[LOGGER=="TwoSmid"]
> TwoStop<-TEMP[LOGGER=="TwoStop"]
```

```
> ThreeSmid<-TEMP[LOGGER=="ThreeSmid"]
> ThreeStop<-TEMP[LOGGER=="ThreeStop"]
> ASmid<-TEMP[LOGGER=="ASmid"]
> AStop<-TEMP[LOGGER=="AStop"]
> CNmid<-TEMP[LOGGER=="CNmid"]
> CNtop<-TEMP[LOGGER=="CNtop"]
> var(Onemid); var(Onetop); var(Twomid); var(Twotop); var(Fourmid); var(Fourtop);
var(Fivemid); var(Fivetop); var(Sixmid); var(Sixtop); var(OneSmid); var(OneStop); var(TwoSmid);
var(TwoStop); var(ThreeSmid); var(ThreeStop); var(ASmid); var(AStop); var(CNmid); var(CNtop)
[1] 4.694119
[1] 26.14581
[1] 4.032725
[1] 24.82665
[1] 3.201204
[1] 23.36075
[1] 3.032218
[1] 21.56854
[1] 3.372873
[1] 22.46455
[1] 2.573789
[1] 28.66121
[1] 2.743706
[1] 29.55369
[1] 3.372035
[1] 28.97642
[1] 18.36793
[1] 20.13778
[1] 11.63152
[1] 20.27318
> TEMP <- aov(TEMP~LOGGER)
> summary(TEMP)
              Df  Sum Sq Mean Sq F value    Pr(>F)
LOGGER        19  558160 29376.9  1939.1 < 2.2e-16 ***
Residuals 175700 2661773    15.1
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

<u>Tukey's Test</u>

```
> TEMP.mcp <- TukeyHSD(TEMP, "LOGGER")
> TEMP.mcp
  Tukey multiple comparisons of means
    95% family-wise confidence level

Fit: aov(formula = TEMP ~ LOGGER)
```

Logger	diff	lwr	upr	p
AStop-ASmid	-0.118353176	-0.326460869	0.089754518	0.8968768
CNmid-ASmid	-0.941159913	-1.149267607	-0.73305222	0
CNtop-ASmid	0.0459028	-0.162204893	0.254010493	0.9999997
Fivemid-ASmid	-3.585014455	-3.793122148	-3.376906762	0
Fivetop-ASmid	-0.094197132	-0.302304825	0.113910561	0.9891716
Fourmid-ASmid	-3.517033804	-3.725141497	-3.30892611	0
Fourtop-ASmid	0.226146597	0.018038904	0.43425429	0.0171
Onemid-ASmid	-2.314519121	-2.522626815	-2.106411428	0
OneSmid-ASmid	-4.591983838	-4.800091531	-4.383876145	0
OneStop-ASmid	0.69014967	0.482041977	0.898257363	0
Onetop-ASmid	0.496097883	0.28799019	0.704205576	0
Sixmid-ASmid	-2.863262008	-3.071369701	-2.655154314	0
Sixtop-ASmid	0.217220692	0.009112999	0.425328385	0.0295841
ThreeSmid-ASmid	-3.460817095	-3.668924789	-3.252709402	0
ThreeStop-ASmid	0.661253699	0.453146006	0.869361392	0
Twomid-ASmid	-2.518480082	-2.726587775	-2.310372389	0
TwoSmid-ASmid	-3.361137491	-3.569245185	-3.153029798	0
TwoStop-ASmid	0.442491691	0.234383998	0.650599385	0
Twotop-ASmid	0.625180742	0.417073049	0.833288435	0
CNmid-AStop	-0.822806738	-1.030914431	-0.614699045	0
CNtop-AStop	0.164255975	-0.043851718	0.372363669	0.3575496
Fivemid-AStop	-3.466661279	-3.674768973	-3.258553586	0
Fivetop-AStop	0.024156044	-0.18395165	0.232263737	1
Fourmid-AStop	-3.398680628	-3.606788322	-3.190572935	0
Fourtop-AStop	0.344499772	0.136392079	0.552607466	0.0000008
Onemid-AStop	-2.196165946	-2.404273639	-1.988058253	0
OneSmid-AStop	-4.473630662	-4.681738356	-4.265522969	0
OneStop-AStop	0.808502845	0.600395152	1.016610539	0
Onetop-AStop	0.614451059	0.406343365	0.822558752	0
Sixmid-AStop	-2.744908832	-2.953016526	-2.536801139	0
Sixtop-AStop	0.335573868	0.127466174	0.543681561	0.0000021
ThreeSmid-AStop	-3.34246392	-3.550571613	-3.134356227	0
ThreeStop-AStop	0.779606875	0.571499181	0.987714568	0
Twomid-AStop	-2.400126906	-2.6082346	-2.192019213	0
TwoSmid-AStop	-3.242784316	-3.450892009	-3.034676623	0
TwoStop-AStop	0.560844867	0.352737174	0.76895256	0
Twotop-AStop	0.743533918	0.535426224	0.951641611	0
CNtop-CNmid	0.987062713	0.77895502	1.195170407	0
Fivemid-CNmid	-2.643854541	-2.851962235	-2.435746848	0
Fivetop-CNmid	0.846962782	0.638855088	1.055070475	0

Fourmid-CNmid	-2.57587389	-2.783981584	-2.367766197	0
Fourtop-CNmid	1.16730651	0.959198817	1.375414204	0
Onemid-CNmid	-1.373359208	-1.581466901	-1.165251515	0
OneSmid-CNmid	-3.650823924	-3.858931618	-3.442716231	0
OneStop-CNmid	1.631309583	1.42320189	1.839417277	0
Onetop-CNmid	1.437257796	1.229150103	1.64536549	0
Sixmid-CNmid	-1.922102094	-2.130209788	-1.713994401	0
Sixtop-CNmid	1.158380606	0.950272912	1.366488299	0
ThreeSmid-CNmid	-2.519657182	-2.727764875	-2.311549489	0
ThreeStop-CNmid	1.602413613	1.394305919	1.810521306	0
Twomid-CNmid	-1.577320168	-1.785427862	-1.369212475	0
TwoSmid-CNmid	-2.419977578	-2.628085271	-2.211869885	0
TwoStop-CNmid	1.383651605	1.175543912	1.591759298	0
Twotop-CNmid	1.566340656	1.358232962	1.774448349	0
Fivemid-CNtop	-3.630917255	-3.839024948	-3.422809561	0
Fivetop-CNtop	-0.140099932	-0.348207625	0.068007762	0.6723553
Fourmid-CNtop	-3.562936604	-3.771044297	-3.35482891	0
Fourtop-CNtop	0.180243797	-0.027863896	0.38835149	0.195819
Onemid-CNtop	-2.360421921	-2.568529615	-2.152314228	0
OneSmid-CNtop	-4.637886638	-4.845994331	-4.429778945	0
OneStop-CNtop	0.64424687	0.436139177	0.852354563	0
Onetop-CNtop	0.450195083	0.24208739	0.658302776	0
Sixmid-CNtop	-2.909164808	-3.117272501	-2.701057114	0
Sixtop-CNtop	0.171317892	-0.036789801	0.379425585	0.2788776
ThreeSmid-CNtop	-3.506719895	-3.714827589	-3.298612202	0
ThreeStop-CNtop	0.615350899	0.407243206	0.823458592	0
Twomid-CNtop	-2.564382882	-2.772490575	-2.356275189	0
TwoSmid-CNtop	-3.407040291	-3.615147985	-3.198932598	0
TwoStop-CNtop	0.396588891	0.188481198	0.604696585	0
Twotop-CNtop	0.579277942	0.371170249	0.787385635	0
Fivetop-Fivemid	3.490817323	3.28270963	3.698925016	0
Fourmid-Fivemid	0.067980651	-0.140127042	0.276088344	0.999854
Fourtop-Fivemid	3.811161052	3.603053358	4.019268745	0
Onemid-Fivemid	1.270495333	1.06238764	1.478603027	0
OneSmid-Fivemid	-1.006969383	-1.215077076	-0.79886169	0
OneStop-Fivemid	4.275164125	4.067056431	4.483271818	0
Onetop-Fivemid	4.081112338	3.873004645	4.289220031	0
Sixmid-Fivemid	0.721752447	0.513644754	0.92986014	0
Sixtop-Fivemid	3.802235147	3.594127454	4.01034284	0
ThreeSmid-Fivemid	0.124197359	-0.083910334	0.332305053	0.8496644
ThreeStop-Fivemid	4.246268154	4.038160461	4.454375847	0

Twomid-Fivemid	1.066534373	0.85842668	1.274642066	0
TwoSmid-Fivemid	0.223876963	0.01576927	0.431984657	0.0197188
TwoStop-Fivemid	4.027506146	3.819398453	4.235613839	0
Twotop-Fivemid	4.210195197	4.002087504	4.41830289	0
Fourmid-Fivetop	-3.422836672	-3.630944365	-3.214728979	0
Fourtop-Fivetop	0.320343729	0.112236035	0.528451422	0.0000091
Onemid-Fivetop	-2.22032199	-2.428429683	-2.012214296	0
OneSmid-Fivetop	-4.497786706	-4.705894399	-4.289679013	0
OneStop-Fivetop	0.784346802	0.576239108	0.992454495	0
Onetop-Fivetop	0.590295015	0.382187322	0.798402708	0
Sixmid-Fivetop	-2.769064876	-2.977172569	-2.560957183	0
Sixtop-Fivetop	0.311417824	0.103310131	0.519525517	0.0000211
ThreeSmid-Fivetop	-3.366619964	-3.574727657	-3.15851227	0
ThreeStop-Fivetop	0.755450831	0.547343138	0.963558524	0
Twomid-Fivetop	-2.42428295	-2.632390643	-2.216175257	0
TwoSmid-Fivetop	-3.26694036	-3.475048053	-3.058832666	0
TwoStop-Fivetop	0.536688823	0.32858113	0.744796516	0
Twotop-Fivetop	0.719377874	0.511270181	0.927485567	0
Fourtop-Fourmid	3.743180401	3.535072707	3.951288094	0
Onemid-Fourmid	1.202514682	0.994406989	1.410622376	0
OneSmid-Fourmid	-1.074950034	-1.283057727	-0.866842341	0
OneStop-Fourmid	4.207183474	3.99907578	4.415291167	0
Onetop-Fourmid	4.013131687	3.805023993	4.22123938	0
Sixmid-Fourmid	0.653771796	0.445664103	0.861879489	0
Sixtop-Fourmid	3.734254496	3.526146802	3.942362189	0
ThreeSmid-Fourmid	0.056216708	-0.151890985	0.264324402	0.9999922
ThreeStop-Fourmid	4.178287503	3.97017981	4.386395196	0
Twomid-Fourmid	0.998553722	0.790446029	1.206661415	0
TwoSmid-Fourmid	0.155896312	-0.052211381	0.364004006	0.4624283
TwoStop-Fourmid	3.959525495	3.751417802	4.167633188	0
Twotop-Fourmid	4.142214546	3.934106853	4.350322239	0
Onemid-Fourtop	-2.540665718	-2.748773411	-2.332558025	0
OneSmid-Fourtop	-4.818130435	-5.026238128	-4.610022741	0
OneStop-Fourtop	0.464003073	0.25589538	0.672110766	0
Onetop-Fourtop	0.269951286	0.061843593	0.478058979	0.0007457
Sixmid-Fourtop	-3.089408605	-3.297516298	-2.881300911	0
Sixtop-Fourtop	-0.008925905	-0.217033598	0.199181788	1
ThreeSmid-Fourtop	-3.686963692	-3.895071386	-3.478855999	0
ThreeStop-Fourtop	0.435107102	0.226999409	0.643214796	0
Twomid-Fourtop	-2.744626679	-2.952734372	-2.536518986	0
TwoSmid-Fourtop	-3.587284088	-3.795391782	-3.379176395	0

TwoStop-Fourtop	0.216345094	0.008237401	0.424452788	0.0311626
Twotop-Fourtop	0.399034145	0.190926452	0.607141839	0
OneSmid-Onemid	-2.277464717	-2.48557241	-2.069357023	0
OneStop-Onemid	3.004668791	2.796561098	3.212776485	0
Onetop-Onemid	2.810617004	2.602509311	3.018724698	0
Sixmid-Onemid	-0.548742886	-0.75685058	-0.340635193	0
Sixtop-Onemid	2.531739813	2.32363212	2.739847507	0
ThreeSmid-Onemid	-1.146297974	-1.354405667	-0.938190281	0
ThreeStop-Onemid	2.97577282	2.767665127	3.183880514	0
Twomid-Onemid	-0.203960961	-0.412068654	0.004146733	0.0627183
TwoSmid-Onemid	-1.04661837	-1.254726063	-0.838510677	0
TwoStop-Onemid	2.757010813	2.548903119	2.965118506	0
Twotop-Onemid	2.939699863	2.73159217	3.147807557	0
OneStop-OneSmid	5.282133508	5.074025815	5.490241201	0
Onetop-OneSmid	5.088081721	4.879974028	5.296189414	0
Sixmid-OneSmid	1.72872183	1.520614137	1.936829523	0
Sixtop-OneSmid	4.80920453	4.601096837	5.017312223	0
ThreeSmid-OneSmid	1.131166743	0.923059049	1.339274436	0
ThreeStop-OneSmid	5.253237537	5.045129844	5.46134523	0
Twomid-OneSmid	2.073503756	1.865396063	2.281611449	0
TwoSmid-OneSmid	1.230846346	1.022738653	1.43895404	0
TwoStop-OneSmid	5.034475529	4.826367836	5.242583223	0
Twotop-OneSmid	5.21716458	5.009056887	5.425272273	0
Onetop-OneStop	-0.194051787	-0.40215948	0.014055906	0.1043688
Sixmid-OneStop	-3.553411678	-3.761519371	-3.345303984	0
Sixtop-OneStop	-0.472928978	-0.681036671	-0.264821285	0
ThreeSmid-OneStop	-4.150966765	-4.359074459	-3.942859072	0
ThreeStop-OneStop	-0.028895971	-0.237003664	0.179211722	1
Twomid-OneStop	-3.208629752	-3.416737445	-3.000522059	0
TwoSmid-OneStop	-4.051287161	-4.259394855	-3.843179468	0
TwoStop-OneStop	-0.247657979	-0.455765672	-0.039550285	0.0040086
Twotop-OneStop	-0.064968928	-0.273076621	0.143138765	0.9999257
Sixmid-Onetop	-3.359359891	-3.567467584	-3.151252197	0
Sixtop-Onetop	-0.278877191	-0.486984884	-0.070769498	0.0003626
ThreeSmid-Onetop	-3.956914978	-4.165022672	-3.748807285	0
ThreeStop-Onetop	0.165155816	-0.042951877	0.373263509	0.34695
Twomid-Onetop	-3.014577965	-3.222685658	-2.806470272	0
TwoSmid-Onetop	-3.857235374	-4.065343068	-3.649127681	0
TwoStop-Onetop	-0.053606192	-0.261713885	0.154501502	0.9999964
Twotop-Onetop	0.129082859	-0.079024834	0.337190552	0.8020645
Sixtop-Sixmid	3.0804827	2.872375006	3.288590393	0

ThreeSmid-Sixmid	-0.597555088	-0.805662781	-0.389447394	0
ThreeStop-Sixmid	3.524515707	3.316408014	3.7326234	0
Twomid-Sixmid	0.344781926	0.136674232	0.552889619	0.0000008
TwoSmid-Sixmid	-0.497875484	-0.705983177	-0.28976779	0
TwoStop-Sixmid	3.305753699	3.097646006	3.513861392	0
Twotop-Sixmid	3.48844275	3.280335057	3.696550443	0
ThreeSmid-Sixtop	-3.678037787	-3.886145481	-3.469930094	0
ThreeStop-Sixtop	0.444033007	0.235925314	0.6521407	0
Twomid-Sixtop	-2.735700774	-2.943808467	-2.527593081	0
TwoSmid-Sixtop	-3.578358183	-3.786465877	-3.37025049	0
TwoStop-Sixtop	0.225270999	0.017163306	0.433378693	0.0180709
Twotop-Sixtop	0.40796005	0.199852357	0.616067743	0
ThreeStop-ThreeSmid	4.122070794	3.913963101	4.330178488	0
Twomid-ThreeSmid	0.942337013	0.73422932	1.150444707	0
TwoSmid-ThreeSmid	0.099679604	-0.108428089	0.307787297	0.9797487
TwoStop-ThreeSmid	3.903308787	3.695201093	4.11141648	0
Twotop-ThreeSmid	4.085997837	3.877890144	4.294105531	0
Twomid-ThreeStop	-3.179733781	-3.387841474	-2.971626088	0
TwoSmid-ThreeStop	-4.022391191	-4.230498884	-3.814283497	0
TwoStop-ThreeStop	-0.218762008	-0.426869701	-0.010654314	0.026976
Twotop-ThreeStop	-0.036072957	-0.24418065	0.172034736	1
TwoSmid-Twomid	-0.84265741	-1.050765103	-0.634549716	0
TwoStop-Twomid	2.960971773	2.75286408	3.169079467	0
Twotop-Twomid	3.143660824	2.935553131	3.351768517	0
TwoStop-TwoSmid	3.803629183	3.595521489	4.011736876	0
Twotop-TwoSmid	3.986318234	3.77821054	4.194425927	0
Twotop-TwoStop	0.182689051	-0.025418643	0.390796744	0.1764217

```
> plot(TEMP.mcp)
```

Summer Data G2 – G3 Analysis

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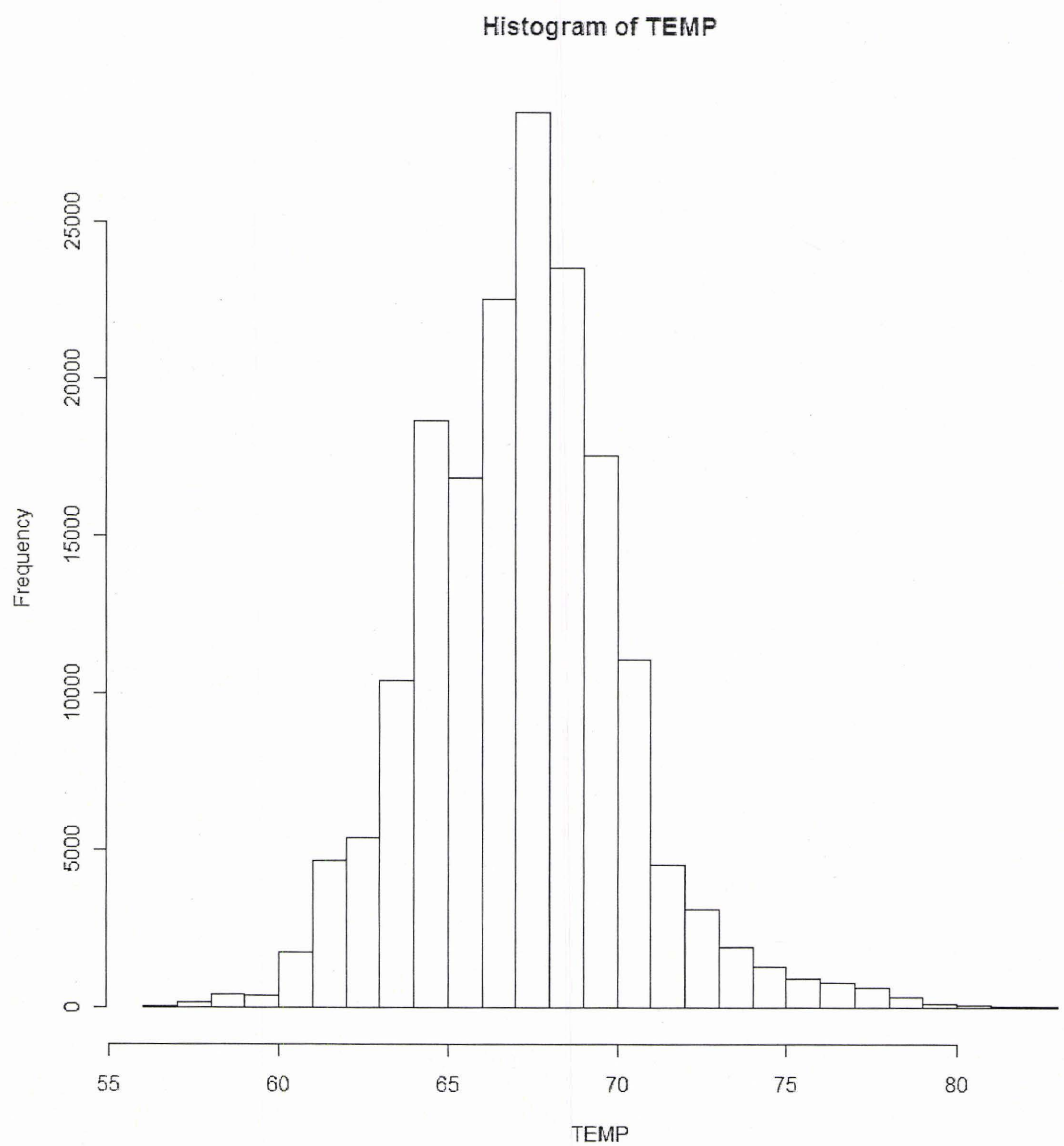
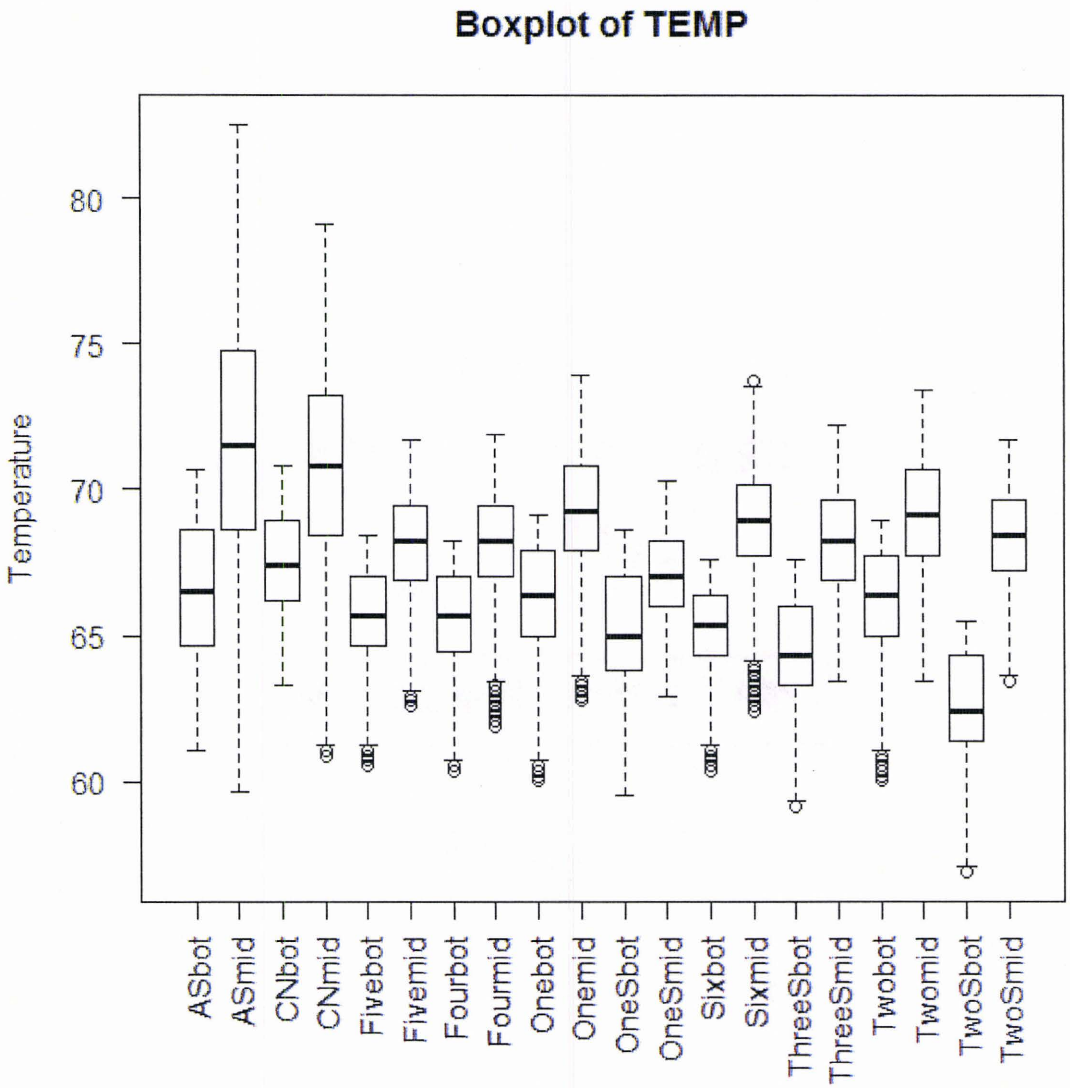
ANOVA Analysis

```
> work <- read.csv("SPRING_BOTMID.txt")
> attach(work)
> hist(TEMP)
```



```
boxplot(TEMP ~ LOGGER,main="Boxplot of TEMP", ylab="Temperature",las=2)
```




```
> Onebot<-TEMP[LOGGER=="Onebot"]
> Onemid<-TEMP[LOGGER=="Onemid"]
> Twobot<-TEMP[LOGGER=="Twobot"]
> Twomid<-TEMP[LOGGER=="Twomid"]
> Fourbot<-TEMP[LOGGER=="Fourbot"]
> Fourmid<-TEMP[LOGGER=="Fourmid"]
> Fivebot<-TEMP[LOGGER=="Fivebot"]
> Fivemid<-TEMP[LOGGER=="Fivemid"]
> Sixbot<-TEMP[LOGGER=="Sixbot"]
> Sixmid<-TEMP[LOGGER=="Sixmid"]
> OneSbot<-TEMP[LOGGER=="OneSbot"]
> OneSmid<-TEMP[LOGGER=="OneSmid"]
> TwoSbot<-TEMP[LOGGER=="TwoSbot"]
> TwoSmid<-TEMP[LOGGER=="TwoSmid"]
```

```
> ThreeSbot<-TEMP[LOGGER=="ThreeSbot"]
> ThreeSmid<-TEMP[LOGGER=="ThreeSmid"]
> ASbot<-TEMP[LOGGER=="ASbot"]
> ASmid<-TEMP[LOGGER=="ASmid"]
> CNbot<-TEMP[LOGGER=="CNbot"]
> CNmid<-TEMP[LOGGER=="CNmid"]
> var(Onebot); var(Onemid); var(Twobot); var(Twomid); var(Fourbot); var(Fourmid);
var(Fivebot); var(Fivemid);  var(Sixbot); var(Sixmid); var(OneSbot); var(OneSmid); var(TwoSbot);
var(TwoSmid); var(ThreeSbot); var(ThreeSmid); var(ASbot); var(ASmid); var(CNbot); var(CNmid);
[1] 3.668941
[1] 4.694119
[1] 3.556332
[1] 4.032725
[1] 2.936350
[1] 3.201204
[1] 2.657394
[1] 3.032218
[1] 2.281162
[1] 3.372873
[1] 4.211927
[1] 2.573789
[1] 3.541797
[1] 2.743706
[1] 3.091707
[1] 3.372035
[1] 6.043354
[1] 18.36793
[1] 3.014591
[1] 11.63152
> TEMP <- aov(TEMP~LOGGER)
> summary(TEMP)
              Df Sum Sq Mean Sq F value    Pr(>F)
LOGGER        19 809218   42590  9256.2 < 2.2e-16 ***
Residuals 175700 808446       5
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Tukey's Test

```
> TEMP.mcp <- TukeyHSD(TEMP, "LOGGER")
> TEMP.mcp
  Tukey multiple comparisons of means
    95% family-wise confidence level


Fit: aov(formula = TEMP ~ LOGGER)
```

Logger	diff	lwr	upr	p
ASmid-ASbot	5.22178136	5.107090711	5.336472	0
CNbot-ASbot	1.02419292	0.909502275	1.13888357	0
CNmid-ASbot	4.28062144	4.165930797	4.39531209	0
Fivebot-ASbot	-0.75430105	-0.868991693	-0.6396104	0
Fivemid-ASbot	1.6367669	1.522076256	1.75145755	0
Fourbot-ASbot	-0.810369	-0.925059642	-0.69567835	0
Fourmid-ASbot	1.70474755	1.590056907	1.8194382	0
Onebot-ASbot	-0.21663954	-0.331330186	-0.10194889	0
Onemid-ASbot	2.90726224	2.79257159	3.02195288	0
OneSbot-ASbot	-1.18326667	-1.29795732	-1.06857603	0
OneSmid-ASbot	0.62979752	0.515106873	0.74448816	0
Sixbot-ASbot	-1.22483895	-1.339529594	-1.1101483	0
Sixmid-ASbot	2.35851935	2.243828703	2.47320999	0
ThreeSbot-ASbot	-1.96815388	-2.082844527	-1.85346324	0
ThreeSmid-ASbot	1.76096426	1.646273616	1.87565491	0
Twobot-ASbot	-0.30058946	-0.415280106	-0.18589881	0
Twomid-ASbot	2.70330127	2.588610629	2.81799192	0
TwoSbot-ASbot	-3.96586012	-4.080550764	-3.85116947	0
TwoSmid-ASbot	1.86064387	1.745953219	1.97533451	0
CNbot-ASmid	-4.19758844	-4.312279082	-4.08289779	0
CNmid-ASmid	-0.94115991	-1.055850559	-0.82646927	0
Fivebot-ASmid	-5.9760824	-6.09077305	-5.86139176	0
Fivemid-ASmid	-3.58501445	-3.699705101	-3.47032381	0
Fourbot-ASmid	-6.03215035	-6.146840999	-5.91745971	0
Fourmid-ASmid	-3.5170338	-3.63172445	-3.40234316	0
Onebot-ASmid	-5.4384209	-5.553111543	-5.32373025	0
Onemid-ASmid	-2.31451912	-2.429209767	-2.19982848	0
OneSbot-ASmid	-6.40504803	-6.519738677	-6.29035739	0
OneSmid-ASmid	-4.59198384	-4.706674484	-4.47729319	0
Sixbot-ASmid	-6.44662031	-6.561310951	-6.33192966	0
Sixmid-ASmid	-2.86326201	-2.977952654	-2.74857136	0
ThreeSbot-ASmid	-7.18993524	-7.304625884	-7.07524459	0
ThreeSmid-ASmid	-3.4608171	-3.575507741	-3.34612645	0
Twobot-ASmid	-5.52237082	-5.637061463	-5.40768017	0
Twomid-ASmid	-2.51848008	-2.633170728	-2.40378944	0
TwoSbot-ASmid	-9.18764148	-9.302332121	-9.07295083	0
TwoSmid-ASmid	-3.36113749	-3.475828137	-3.24644685	0
CNmid-CNbot	3.25642852	3.141737877	3.37111917	0
Fivebot-CNbot	-1.77849397	-1.893184613	-1.66380332	0
Fivemid-CNbot	0.61257398	0.497883336	0.72726463	0

Fourbot-CNbot	-1.83456192	-1.949252562	-1.71987127	0
Fourmid-CNbot	0.68055463	0.565863987	0.79524528	0
Onebot-CNbot	-1.24083246	-1.355523107	-1.12614181	0
Onemid-CNbot	1.88306931	1.768378669	1.99775996	0
OneSbot-CNbot	-2.20745959	-2.322150241	-2.09276895	0
OneSmid-CNbot	-0.3943954	-0.509086048	-0.27970476	0
Sixbot-CNbot	-2.24903187	-2.363722515	-2.13434122	0
Sixmid-CNbot	1.33432643	1.219635783	1.44901707	0
ThreeSbot-CNbot	-2.9923468	-3.107037448	-2.87765616	0
ThreeSmid-CNbot	0.73677134	0.622080695	0.85146199	0
Twobot-CNbot	-1.32478238	-1.439473027	-1.21009174	0
Twomid-CNbot	1.67910835	1.564417708	1.793799	0
TwoSbot-CNbot	-4.99005304	-5.104743685	-4.87536239	0
TwoSmid-CNbot	0.83645094	0.721760299	0.95114159	0
Fivebot-CNmid	-5.03492249	-5.149613136	-4.92023184	0
Fivemid-CNmid	-2.64385454	-2.758545187	-2.5291639	0
Fourbot-CNmid	-5.09099044	-5.205681085	-4.97629979	0
Fourmid-CNmid	-2.57587389	-2.690564536	-2.46118324	0
Onebot-CNmid	-4.49726098	-4.611951629	-4.38257034	0
Onemid-CNmid	-1.37335921	-1.488049854	-1.25866856	0
OneSbot-CNmid	-5.46388812	-5.578578763	-5.34919747	0
OneSmid-CNmid	-3.65082392	-3.76551457	-3.53613328	0
Sixbot-CNmid	-5.50546039	-5.620151037	-5.39076975	0
Sixmid-CNmid	-1.92210209	-2.03679274	-1.80741145	0
ThreeSbot-CNmid	-6.24877532	-6.36346597	-6.13408468	0
ThreeSmid-CNmid	-2.51965718	-2.634347828	-2.40496654	0
Twobot-CNmid	-4.5812109	-4.69590155	-4.46652026	0
Twomid-CNmid	-1.57732017	-1.692010814	-1.46262952	0
TwoSbot-CNmid	-8.24648156	-8.361172207	-8.13179092	0
TwoSmid-CNmid	-2.41997758	-2.534668224	-2.30528693	0
Fivemid-Fivebot	2.39106795	2.276377303	2.50575859	0
Fourbot-Fivebot	-0.05606795	-0.170758595	0.0586227	0.9748758
Fourmid-Fivebot	2.4590486	2.344357954	2.57373925	0
Onebot-Fivebot	0.53766151	0.422970861	0.65235215	0
Onemid-Fivebot	3.66156328	3.546872637	3.77625393	0
OneSbot-Fivebot	-0.42896563	-0.543656273	-0.31427498	0
OneSmid-Fivebot	1.38409857	1.26940792	1.49878921	0
Sixbot-Fivebot	-0.4705379	-0.585228547	-0.35584726	0
Sixmid-Fivebot	3.1128204	2.99812975	3.22751104	0
ThreeSbot-Fivebot	-1.21385283	-1.32854348	-1.09916219	0
ThreeSmid-Fivebot	2.51526531	2.400574663	2.62995595	0

Twobot-Fivebot	0.45371159	0.339020941	0.56840223	0
Twomid-Fivebot	3.45760232	3.342911676	3.57229297	0
TwoSbot-Fivebot	-3.21155907	-3.326249717	-3.09686843	0
TwoSmid-Fivebot	2.61494491	2.500254267	2.72963556	0
Fourbot-Fivemid	-2.4471359	-2.561826544	-2.33244525	0
Fourmid-Fivemid	0.06798065	-0.046709995	0.1826713	0.8571666
Onebot-Fivemid	-1.85340644	-1.968097088	-1.7387158	0
Onemid-Fivemid	1.27049533	1.155804688	1.38518598	0
OneSbot-Fivemid	-2.82003358	-2.934724222	-2.70534293	0
OneSmid-Fivemid	-1.00696938	-1.121660029	-0.89227874	0
Sixbot-Fivemid	-2.86160585	-2.976296496	-2.7469152	0
Sixmid-Fivemid	0.72175245	0.607061801	0.83644309	0
ThreeSbot-Fivemid	-3.60492078	-3.719611429	-3.49023014	0
ThreeSmid-Fivemid	0.12419736	0.009506714	0.23888801	0.0179725
Twobot-Fivemid	-1.93735636	-2.052047008	-1.82266572	0
Twomid-Fivemid	1.06653437	0.951843727	1.18122502	0
TwoSbot-Fivemid	-5.60262702	-5.717317666	-5.48793637	0
TwoSmid-Fivemid	0.22387696	0.109186318	0.33856761	0
Fourmid-Fourbot	2.51511655	2.400425903	2.62980719	0
Onebot-Fourbot	0.59372946	0.47903881	0.7084201	0
Onemid-Fourbot	3.71763123	3.602940586	3.83232188	0
OneSbot-Fourbot	-0.37289768	-0.487588324	-0.25820703	0
OneSmid-Fourbot	1.44016651	1.325475869	1.55485716	0
Sixbot-Fourbot	-0.41446995	-0.529160598	-0.29977931	0
Sixmid-Fourbot	3.16888835	3.054197699	3.28357899	0
ThreeSbot-Fourbot	-1.15778489	-1.272475531	-1.04309424	0
ThreeSmid-Fourbot	2.57133326	2.456642612	2.6860239	0
Twobot-Fourbot	0.50977954	0.39508889	0.62447018	0
Twomid-Fourbot	3.51367027	3.398979625	3.62836092	0
TwoSbot-Fourbot	-3.15549112	-3.270181768	-3.04080048	0
TwoSmid-Fourbot	2.67101286	2.556322216	2.78570351	0
Onebot-Fourmid	-1.92138709	-2.036077739	-1.80669645	0
Onemid-Fourmid	1.20251468	1.087824037	1.31720533	0
OneSbot-Fourmid	-2.88801423	-3.002704873	-2.77332358	0
OneSmid-Fourmid	-1.07495003	-1.18964068	-0.96025939	0
Sixbot-Fourmid	-2.9295865	-3.044277147	-2.81489586	0
Sixmid-Fourmid	0.6537718	0.53908115	0.76846244	0
ThreeSbot-Fourmid	-3.67290143	-3.78759208	-3.55821079	0
ThreeSmid-Fourmid	0.05621671	-0.058473937	0.17090735	0.9741737
Twobot-Fourmid	-2.00533701	-2.120027659	-1.89064637	0
Twomid-Fourmid	0.99855372	0.883863076	1.11324437	0

TwoSbot-Fourmid	-5.67060767	-5.785298317	-5.55591703	0
TwoSmid-Fourmid	0.15589631	0.041205667	0.27058696	0.0002603
Onemid-Onebot	3.12390178	3.00921113	3.23859242	0
OneSbot-Onebot	-0.96662713	-1.08131778	-0.85193649	0
OneSmid-Onebot	0.84643706	0.731746413	0.9611277	0
Sixbot-Onebot	-1.00819941	-1.122890054	-0.89350876	0
Sixmid-Onebot	2.57515889	2.460468243	2.68984953	0
ThreeSbot-Onebot	-1.75151434	-1.866204987	-1.6368237	0
ThreeSmid-Onebot	1.9776038	1.862913156	2.09229445	0
Twobot-Onebot	-0.08394992	-0.198640566	0.03074073	0.509713
Twomid-Onebot	2.91994081	2.805250169	3.03463146	0
TwoSbot-Onebot	-3.74922058	-3.863911224	-3.63452993	0
TwoSmid-Onebot	2.07728341	1.96259276	2.19197405	0
OneSbot-Onemid	-4.09052891	-4.205219555	-3.97583826	0
OneSmid-Onemid	-2.27746472	-2.392155362	-2.16277407	0
Sixbot-Onemid	-4.13210118	-4.24679183	-4.01741054	0
Sixmid-Onemid	-0.54874289	-0.663433532	-0.43405224	0
ThreeSbot-Onemid	-4.87541612	-4.990106762	-4.76072547	0
ThreeSmid-Onemid	-1.14629797	-1.26098862	-1.03160733	0
Twobot-Onemid	-3.2078517	-3.322542342	-3.09316105	0
Twomid-Onemid	-0.20396096	-0.318651606	-0.08927031	0.0000001
TwoSbot-Onemid	-6.87312235	-6.987813	-6.75843171	0
TwoSmid-Onemid	-1.04661837	-1.161309016	-0.93192772	0
OneSmid-OneSbot	1.81306419	1.698373547	1.92775484	0
Sixbot-OneSbot	-0.04157227	-0.15626292	0.07311837	0.9993545
Sixmid-OneSbot	3.54178602	3.427095377	3.65647667	0
ThreeSbot-OneSbot	-0.78488721	-0.899577853	-0.67019656	0
ThreeSmid-OneSbot	2.94423094	2.82954029	3.05892158	0
Twobot-OneSbot	0.88267721	0.767986568	0.99736786	0
Twomid-OneSbot	3.88656795	3.771877303	4.00125859	0
TwoSbot-OneSbot	-2.78259344	-2.89728409	-2.6679028	0
TwoSmid-OneSbot	3.04391054	2.929219894	3.15860119	0
Sixbot-OneSmid	-1.85463647	-1.969327113	-1.73994582	0
Sixmid-OneSmid	1.72872183	1.614031184	1.84341248	0
ThreeSbot-OneSmid	-2.5979514	-2.712642046	-2.48326075	0
ThreeSmid-OneSmid	1.13116674	1.016476097	1.24585739	0
Twobot-OneSmid	-0.93038698	-1.045077625	-0.81569633	0
Twomid-OneSmid	2.07350376	1.95881311	2.1881944	0
TwoSbot-OneSmid	-4.59565764	-4.710348283	-4.48096699	0
TwoSmid-OneSmid	1.23084635	1.116155701	1.34553699	0
Sixmid-Sixbot	3.5833583	3.468667651	3.69804894	0

ThreeSbot-Sixbot	-0.74331493	-0.858005579	-0.62862429	0
ThreeSmid-Sixbot	2.98580321	2.871112564	3.10049386	0
Twobot-Sixbot	0.92424949	0.809558842	1.03894013	0
Twomid-Sixbot	3.92814022	3.813449577	4.04283087	0
TwoSbot-Sixbot	-2.74102117	-2.855711816	-2.62633052	0
TwoSmid-Sixbot	3.08548281	2.970792168	3.20017346	0
ThreeSbot-Sixmid	-4.32667323	-4.441363876	-4.21198258	0
ThreeSmid-Sixmid	-0.59755509	-0.712245733	-0.48286444	0
Twobot-Sixmid	-2.65910881	-2.773799455	-2.54441816	0
Twomid-Sixmid	0.34478193	0.23009128	0.45947257	0
TwoSbot-Sixmid	-6.32437947	-6.439070113	-6.20968882	0
TwoSmid-Sixmid	-0.49787548	-0.61256613	-0.38318484	0
ThreeSmid-ThreeSbot	3.72911814	3.614427497	3.84380879	0
Twobot-ThreeSbot	1.66756442	1.552873775	1.78225507	0
Twomid-ThreeSbot	4.67145516	4.55676451	4.7861458	0
TwoSbot-ThreeSbot	-1.99770624	-2.112396883	-1.88301559	0
TwoSmid-ThreeSbot	3.82879775	3.714107101	3.94348839	0
Twobot-ThreeSmid	-2.06155372	-2.176244368	-1.94686308	0
Twomid-ThreeSmid	0.94233701	0.827646368	1.05702766	0
TwoSbot-ThreeSmid	-5.72682438	-5.841515026	-5.61213373	0
TwoSmid-ThreeSmid	0.0996796	-0.015011042	0.21437025	0.1907147
Twomid-Twobot	3.00389074	2.889200089	3.11858138	0
TwoSbot-Twobot	-3.66527066	-3.779961304	-3.55058001	0
TwoSmid-Twobot	2.16123333	2.04654268	2.27592397	0
TwoSbot-Twomid	-6.66916139	-6.783852039	-6.55447075	0
TwoSmid-Twomid	-0.84265741	-0.957348055	-0.72796676	0
TwoSmid-TwoSbot	5.82650398	5.711813338	5.94119463	0

```
> plot(TEMP.mcp)
>
```

Fall Data G1 – G2 Analysis

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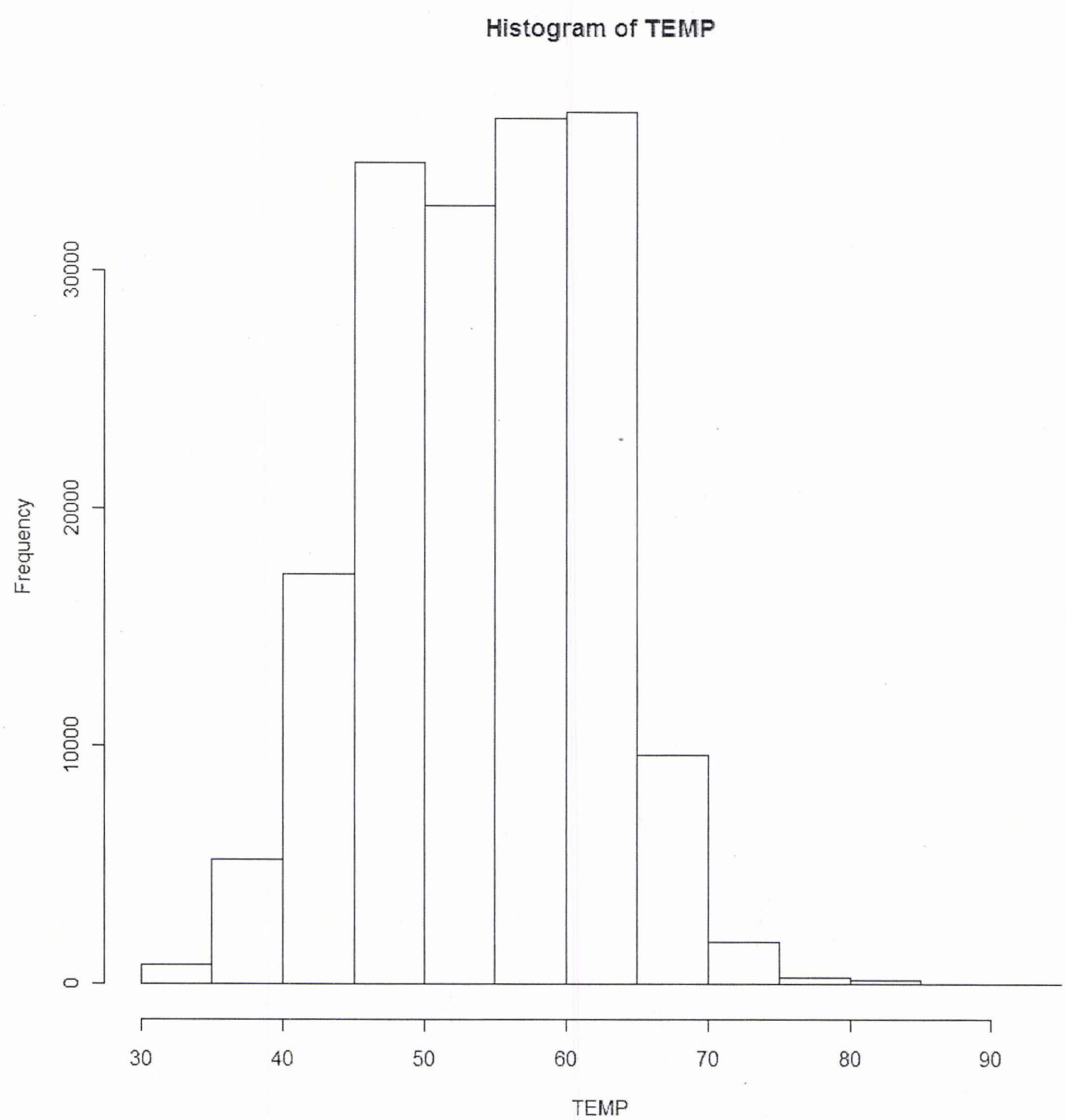
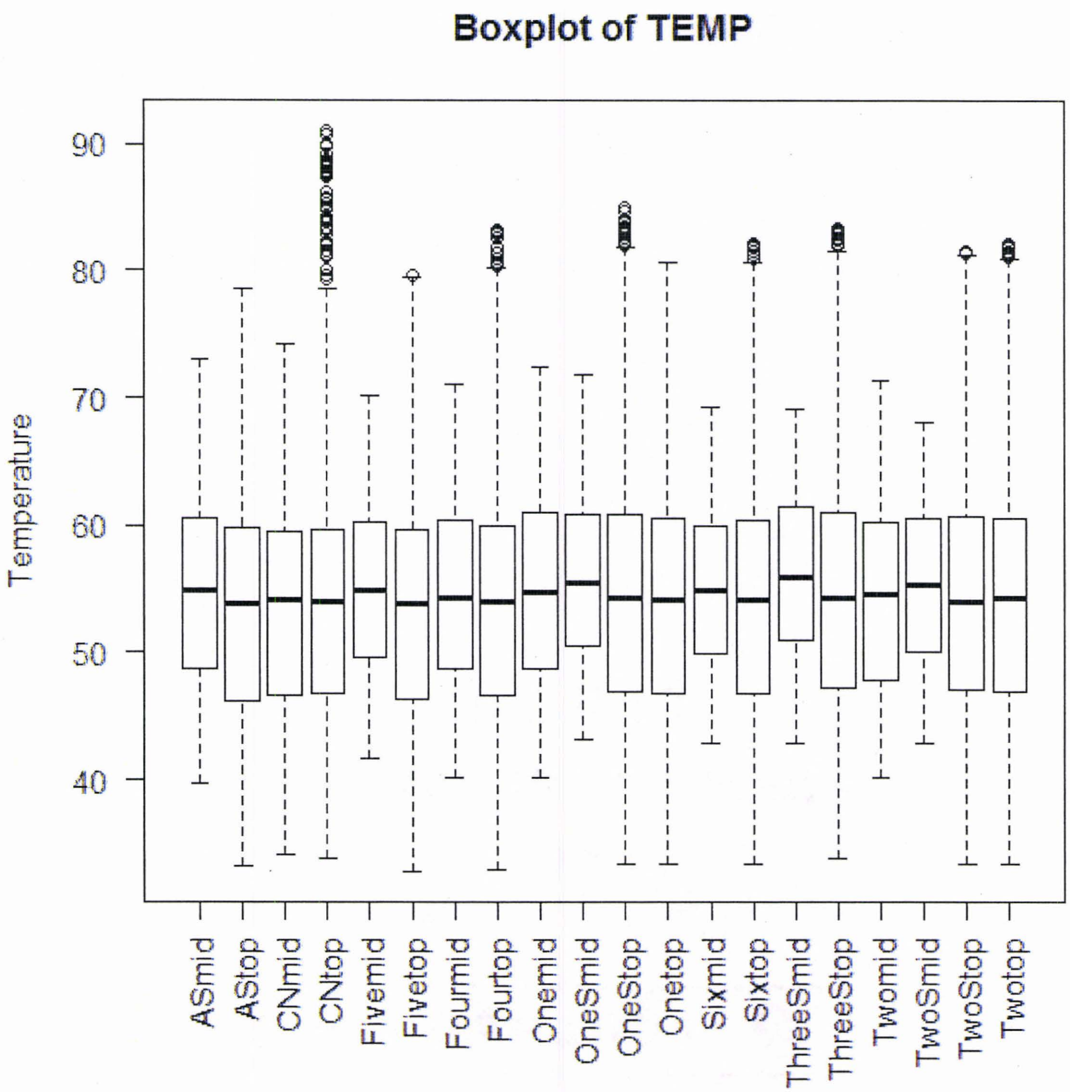
ANOVA Analysis

```
> work <- read.csv("FALL_TOPMID.txt")
> attach(work)
> hist(TEMP)
```



```
> boxplot(TEMP ~ LOGGER,main="Boxplot of TEMP", ylab="Temperature",las=2)
```




```
> Onemid<-TEMP[LOGGER=="Onemid"]
> Onetop<-TEMP[LOGGER=="Onetop"]
> Twomid<-TEMP[LOGGER=="Twomid"]
> Twotop<-TEMP[LOGGER=="Twotop"]
> Fourmid<-TEMP[LOGGER=="Fourmid"]
> Fourtop<-TEMP[LOGGER=="Fourtop"]
> Fivemid<-TEMP[LOGGER=="Fivemid"]
> Fivetop<-TEMP[LOGGER=="Fivetop"]
> Sixmid<-TEMP[LOGGER=="Sixmid"]
> Sixtop<-TEMP[LOGGER=="Sixtop"]
> OneSmid<-TEMP[LOGGER=="OneSmid"]
> OneStop<-TEMP[LOGGER=="OneStop"]
> TwoSmid<-TEMP[LOGGER=="TwoSmid"]
> TwoStop<-TEMP[LOGGER=="TwoStop"]
```

```
> ThreeSmid<-TEMP[LOGGER=="ThreeSmid"]
> ThreeStop<-TEMP[LOGGER=="ThreeStop"]
> ASmid<-TEMP[LOGGER=="ASmid"]
> AStop<-TEMP[LOGGER=="AStop"]
> CNmid<-TEMP[LOGGER=="CNmid"]
> CNtop<-TEMP[LOGGER=="CNtop"]
> var(Onemid); var(Onetop); var(Twomid); var(Twotop); var(Fourmid); var(Fourtop);
var(Fivemid); var(Fivetop); var(Sixmid); var(Sixtop); var(OneSmid); var(OneStop); var(TwoSmid);
var(TwoStop); var(ThreeSmid); var(ThreeStop); var(ASmid); var(AStop); var(CNmid); var(CNtop)
[1] 52.1644
[1] 77.83306
[1] 51.65547
[1] 76.97541
[1] 50.15681
[1] 75.87166
[1] 43.03853
[1] 73.72632
[1] 36.99531
[1] 74.81703
[1] 40.9202
[1] 80.39723
[1] 39.20385
[1] 80.76942
[1] 41.41495
[1] 79.87522
[1] 50.89247
[1] 72.02949
[1] 63.00635
[1] 71.72274
> TEMP <- aov(TEMP~LOGGER)
> summary(TEMP)
              Df   Sum Sq Mean Sq F value    Pr(>F)
LOGGER        19   109982  5788.5  93.858 < 2.2e-16 ***
Residuals 175560 10827364    61.7
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Tukey's Test

```
>
> TEMP.mcp <- TukeyHSD(TEMP, "LOGGER")
> TEMP.mcp
  Tukey multiple comparisons of means
    95% family-wise confidence level

Fit: aov(formula = TEMP ~ LOGGER)
```

Logger	diff	lwr	upr	p
AStop-ASmid	-1.45549208	-1.87555095	-1.035433221	0
CNmid-ASmid	-1.50516107	-1.92521993	-1.085102204	0
CNtop-ASmid	-1.19487299	-1.61493185	-0.77481413	0
Fivemid-ASmid	0.20421882	-0.21584004	0.62427768	0.9762872
Fivetop-ASmid	-1.29202495	-1.71208381	-0.871966084	0
Fourmid-ASmid	-0.27213931	-0.69219817	0.147919552	0.7377424
Fourtop-ASmid	-1.11854721	-1.53860608	-0.698488353	0
Onemid-ASmid	0.15907939	-0.26097947	0.579138256	0.9988272
OneSmid-ASmid	1.03025026	0.61019139	1.450309118	0
OneStop-ASmid	-0.39961681	-0.81967567	0.020442049	0.0857633
Onetop-ASmid	-0.60910673	-1.02916559	-0.18904787	0.0000507
Sixmid-ASmid	0.40243558	-0.01762328	0.822494447	0.0798396
Sixtop-ASmid	-0.85511903	-1.2751779	-0.435060172	0
ThreeSmid-ASmid	1.48961829	1.06955943	1.909677156	0
ThreeStop-ASmid	-0.08560417	-0.50566303	0.334454693	0.9999999
Twomid-ASmid	-0.46301561	-0.88307447	-0.042956743	0.0138998
TwoSmid-ASmid	0.53860337	0.11854451	0.958662234	0.000953
TwoStop-ASmid	-0.42097699	-0.84103585	-0.000918129	0.0487494
Twotop-ASmid	-0.56104215	-0.98110101	-0.140983284	0.0003912
CNmid-AStop	-0.04966898	-0.46972784	0.370389879	1
CNtop-AStop	0.26061909	-0.15943977	0.680677953	0.8017049
Fivemid-AStop	1.6597109	1.23965204	2.079769763	0
Fivetop-AStop	0.16346714	-0.25659172	0.583526	0.9983165
Fourmid-AStop	1.18335277	0.76329391	1.603411636	0
Fourtop-AStop	0.33694487	-0.08311399	0.75700373	0.3265104
Onemid-AStop	1.61457148	1.19451262	2.034630339	0
OneSmid-AStop	2.48574234	2.06568348	2.905801202	0
OneStop-AStop	1.05587527	0.63581641	1.475934133	0
Onetop-AStop	0.84638535	0.42632649	1.266444213	0
Sixmid-AStop	1.85792767	1.43786881	2.27798653	0
Sixtop-AStop	0.60037305	0.18031419	1.020431911	0.0000745
ThreeSmid-AStop	2.94511038	2.52505152	3.365169239	0
ThreeStop-AStop	1.36988791	0.94982905	1.789946776	0
Twomid-AStop	0.99247648	0.57241762	1.41253534	0
TwoSmid-AStop	1.99409546	1.57403659	2.414154317	0
TwoStop-AStop	1.03451509	0.61445623	1.454573955	0
Twotop-AStop	0.89444994	0.47439108	1.314508799	0
CNtop-CNmid	0.31028807	-0.10977079	0.730346936	0.4910971
Fivemid-CNmid	1.70937988	1.28932102	2.129438746	0
Fivetop-CNmid	0.21313612	-0.20692274	0.633194982	0.9633295

Fourmid-CNmid	1.23302176	0.81296289	1.653080619	0
Fourtop-CNmid	0.38661385	-0.03344501	0.806672713	0.1178754
Onemid-CNmid	1.66424046	1.2441816	2.084299322	0
OneSmid-CNmid	2.53541132	2.11535246	2.955470185	0
OneStop-CNmid	1.10554425	0.68548539	1.525603115	0
Onetop-CNmid	0.89605433	0.47599547	1.316113196	0
Sixmid-CNmid	1.90759665	1.48753779	2.327655513	0
Sixtop-CNmid	0.65004203	0.22998317	1.070100894	0.0000078
ThreeSmid-CNmid	2.99477936	2.5747205	3.414838222	0
ThreeStop-CNmid	1.4195569	0.99949804	1.839615759	0
Twomid-CNmid	1.04214546	0.6220866	1.462204323	0
TwoSmid-CNmid	2.04376444	1.62370558	2.4638233	0
TwoStop-CNmid	1.08418408	0.66412521	1.504242938	0
Twotop-CNmid	0.94411892	0.52406006	1.364177782	0
Fivemid-CNtop	1.39909181	0.97903295	1.819150672	0
Fivetop-CNtop	-0.09715195	-0.51721082	0.322906909	0.9999994
Fourmid-CNtop	0.92273368	0.50267482	1.342792545	0
Fourtop-CNtop	0.07632578	-0.34373308	0.496384639	1
Onemid-CNtop	1.35395239	0.93389352	1.774011248	0
OneSmid-CNtop	2.22512325	1.80506439	2.645182111	0
OneStop-CNtop	0.79525618	0.37519732	1.215315042	0
Onetop-CNtop	0.58576626	0.1657074	1.005825122	0.0001399
Sixmid-CNtop	1.59730858	1.17724972	2.017367439	0
Sixtop-CNtop	0.33975396	-0.0803049	0.75981282	0.3109427
ThreeSmid-CNtop	2.68449129	2.26443242	3.104550148	0
ThreeStop-CNtop	1.10926882	0.68920996	1.529327685	0
Twomid-CNtop	0.73185739	0.31179852	1.151916249	0.0000001
TwoSmid-CNtop	1.73347636	1.3134175	2.153535226	0
TwoStop-CNtop	0.773896	0.35383714	1.193954864	0
Twotop-CNtop	0.63383085	0.21377198	1.053889708	0.0000166
Fivetop-Fivemid	-1.49624376	-1.91630263	-1.076184902	0
Fourmid-Fivemid	-0.47635813	-0.89641699	-0.056299265	0.0089949
Fourtop-Fivemid	-1.32276603	-1.74282489	-0.902707171	0
Onemid-Fivemid	-0.04513942	-0.46519829	0.374919438	1
OneSmid-Fivemid	0.82603144	0.40597258	1.246090301	0
OneStop-Fivemid	-0.60383563	-1.02389449	-0.183776769	0.000064
Onetop-Fivemid	-0.81332555	-1.23338441	-0.393266688	0
Sixmid-Fivemid	0.19821677	-0.22184209	0.618275629	0.982765
Sixtop-Fivemid	-1.05933785	-1.47939671	-0.63927899	0
ThreeSmid-Fivemid	1.28539948	0.86534061	1.705458338	0
ThreeStop-Fivemid	-0.28982299	-0.70988185	0.130235875	0.6268743

Twomid-Fivemid	-0.66723442	-1.08729329	-0.247175561	0.0000034
TwoSmid-Fivemid	0.33438455	-0.08567431	0.754443416	0.3410512
TwoStop-Fivemid	-0.62519581	-1.04525467	-0.205136946	0.0000246
Twotop-Fivemid	-0.76526096	-1.18531983	-0.345202102	0
Fourmid-Fivetop	1.01988564	0.59982677	1.439944498	0
Fourtop-Fivetop	0.17347773	-0.24658113	0.593536593	0.99639
Onemid-Fivetop	1.45110434	1.03104548	1.871163202	0
OneSmid-Fivetop	2.3222752	1.90221634	2.742334064	0
OneStop-Fivetop	0.89240813	0.47234927	1.312466995	0
Onetop-Fivetop	0.68291821	0.26285935	1.102977076	0.0000016
Sixmid-Fivetop	1.69446053	1.27440167	2.114519393	0
Sixtop-Fivetop	0.43690591	0.01684705	0.856964774	0.0309621
ThreeSmid-Fivetop	2.78164324	2.36158438	3.201702102	0
ThreeStop-Fivetop	1.20642078	0.78636191	1.626479639	0
Twomid-Fivetop	0.82900934	0.40895048	1.249068203	0
TwoSmid-Fivetop	1.83062832	1.41056946	2.25068718	0
TwoStop-Fivetop	0.87104796	0.45098909	1.291106817	0
Twotop-Fivetop	0.7309828	0.31092394	1.151041662	0.0000001
Fourtop-Fourmid	-0.84640791	-1.26646677	-0.426349043	0
Onemid-Fourmid	0.4312187	0.01115984	0.851277566	0.0365228
OneSmid-Fourmid	1.30238957	0.8823307	1.722448428	0
OneStop-Fourmid	-0.1274775	-0.54753637	0.292581359	0.9999516
Onetop-Fourmid	-0.33696742	-0.75702628	0.08309144	0.3263838
Sixmid-Fourmid	0.67457489	0.25451603	1.094633757	0.0000024
Sixtop-Fourmid	-0.58297972	-1.00303859	-0.162920862	0.0001575
ThreeSmid-Fourmid	1.7617576	1.34169874	2.181816465	0
ThreeStop-Fourmid	0.18653514	-0.23352372	0.606594003	0.9913158
Twomid-Fourmid	-0.1908763	-0.61093516	0.229182566	0.9886796
TwoSmid-Fourmid	0.81074268	0.39068382	1.230801543	0
TwoStop-Fourmid	-0.14883768	-0.56889654	0.271221181	0.9995298
Twotop-Fourmid	-0.28890284	-0.7089617	0.131156026	0.6328961
Onemid-Fourtop	1.27762661	0.85756775	1.697685471	0
OneSmid-Fourtop	2.14879747	1.72873861	2.568856333	0
OneStop-Fourtop	0.7189304	0.29887154	1.138989264	0.0000002
Onetop-Fourtop	0.50944048	0.08938162	0.929499345	0.0028466
Sixmid-Fourtop	1.5209828	1.10092394	1.941041662	0
Sixtop-Fourtop	0.26342818	-0.15663068	0.683487043	0.7868747
ThreeSmid-Fourtop	2.60816551	2.18810665	3.028224371	0
ThreeStop-Fourtop	1.03294305	0.61288418	1.453001908	0
Twomid-Fourtop	0.65553161	0.23547275	1.075590472	0.000006
TwoSmid-Fourtop	1.65715059	1.23709172	2.077209449	0

TwoStop-Fourtop	0.69757022	0.27751136	1.117629086	0.0000007
Twotop-Fourtop	0.55750507	0.13744621	0.977563931	0.0004513
OneSmid-Onemid	0.87117086	0.451112	1.291229724	0
OneStop-Onemid	-0.55869621	-0.97875507	-0.138637345	0.0004301
Onetop-Onemid	-0.76818613	-1.18824499	-0.348127264	0
Sixmid-Onemid	0.24335619	-0.17670267	0.663415053	0.8802931
Sixtop-Onemid	-1.01419843	-1.43425729	-0.594139566	0
ThreeSmid-Onemid	1.3305389	0.91048004	1.750597762	0
ThreeStop-Onemid	-0.24468356	-0.66474243	0.175375299	0.8750595
Twomid-Onemid	-0.622095	-1.04215386	-0.202036137	0.0000283
TwoSmid-Onemid	0.37952398	-0.04053488	0.79958284	0.1389959
TwoStop-Onemid	-0.58005638	-1.00011525	-0.159997523	0.0001782
Twotop-Onemid	-0.72012154	-1.1401804	-0.300062678	0.0000002
OneStop-OneSmid	-1.42986707	-1.84992593	-1.009808207	0
Onetop-OneSmid	-1.63935699	-2.05941585	-1.219298126	0
Sixmid-OneSmid	-0.62781467	-1.04787353	-0.207755809	0.0000218
Sixtop-OneSmid	-1.88536929	-2.30542815	-1.465310428	0
ThreeSmid-OneSmid	0.45936804	0.03930918	0.879426899	0.0156092
ThreeStop-OneSmid	-1.11585443	-1.53591329	-0.695795563	0
Twomid-OneSmid	-1.49326586	-1.91332472	-1.073207	0
TwoSmid-OneSmid	-0.49164688	-0.91170575	-0.071588023	0.0053513
TwoStop-OneSmid	-1.45122725	-1.87128611	-1.031168385	0
Twotop-OneSmid	-1.5912924	-2.01135126	-1.17123354	0
Onetop-OneStop	-0.20948992	-0.62954878	0.210568943	0.9691536
Sixmid-OneStop	0.8020524	0.38199354	1.22211126	0
Sixtop-OneStop	-0.45550222	-0.87556108	-0.035443359	0.0176256
ThreeSmid-OneStop	1.88923511	1.46917624	2.309293969	0
ThreeStop-OneStop	0.31401264	-0.10604622	0.734071506	0.4667124
Twomid-OneStop	-0.06339879	-0.48345765	0.356660069	1
TwoSmid-OneStop	0.93822018	0.51816132	1.358279047	0
TwoStop-OneStop	-0.02136018	-0.44141904	0.398698684	1
Twotop-OneStop	-0.16142533	-0.5814842	0.258633529	0.9985741
Sixmid-Onetop	1.01154232	0.59148345	1.431601179	0
Sixtop-Onetop	-0.2460123	-0.66607116	0.17404656	0.869682
ThreeSmid-Onetop	2.09872503	1.67866616	2.518783888	0
ThreeStop-Onetop	0.52350256	0.1034437	0.943561425	0.0016948
Twomid-Onetop	0.14609113	-0.27396774	0.566149989	0.9996386
TwoSmid-Onetop	1.1477101	0.72765124	1.567768966	0
TwoStop-Onetop	0.18812974	-0.23192912	0.608188603	0.9904135
Twotop-Onetop	0.04806459	-0.37199428	0.468123448	1
Sixtop-Sixmid	-1.25755462	-1.67761348	-0.837495757	0

ThreeSmid-Sixmid	1.08718271	0.66712385	1.507241571	0
ThreeStop-Sixmid	-0.48803975	-0.90809862	-0.067980892	0.0060606
Twomid-Sixmid	-0.86545119	-1.28551005	-0.445392328	0
TwoSmid-Sixmid	0.13616779	-0.28389108	0.556226649	0.9998697
TwoStop-Sixmid	-0.82341258	-1.24347144	-0.403353714	0
Twotop-Sixmid	-0.96347773	-1.38353659	-0.543418869	0
ThreeSmid-Sixtop	2.34473733	1.92467847	2.76479619	0
ThreeStop-Sixtop	0.76951487	0.349456	1.189573727	0
Twomid-Sixtop	0.39210343	-0.02795543	0.812162291	0.1033185
TwoSmid-Sixtop	1.39372241	0.97366354	1.813781268	0
TwoStop-Sixtop	0.43414204	0.01408318	0.854200906	0.0335642
Twotop-Sixtop	0.29407689	-0.12598197	0.71413575	0.5988278
ThreeStop-ThreeSmid	-1.57522246	-1.99528132	-1.155163601	0
Twomid-ThreeSmid	-1.9526339	-2.37269276	-1.532575037	0
TwoSmid-ThreeSmid	-0.95101492	-1.37107378	-0.53095606	0
TwoStop-ThreeSmid	-1.91059528	-2.33065415	-1.490536422	0
Twotop-ThreeSmid	-2.05066044	-2.4707193	-1.630601578	0
Twomid-ThreeStop	-0.37741144	-0.7974703	0.042647426	0.1458173
TwoSmid-ThreeStop	0.62420754	0.20414868	1.044266403	0.0000257
TwoStop-ThreeStop	-0.33537282	-0.75543168	0.084686041	0.3353997
Twotop-ThreeStop	-0.47543798	-0.89549684	-0.055379115	0.0092741
TwoSmid-Twomid	1.00161898	0.58156012	1.421677839	0
TwoStop-Twomid	0.04203861	-0.37802025	0.462097477	1
Twotop-Twomid	-0.09802654	-0.5180854	0.322032321	0.9999993
TwoStop-TwoSmid	-0.95958036	-1.37963922	-0.5395215	0
Twotop-TwoSmid	-1.09964552	-1.51970438	-0.679586656	0
Twotop-TwoStop	-0.14006516	-0.56012402	0.279993707	0.9998028

```
> plot(TEMP.mcp)
>
```

Fall Data G2 – G3 Analysis

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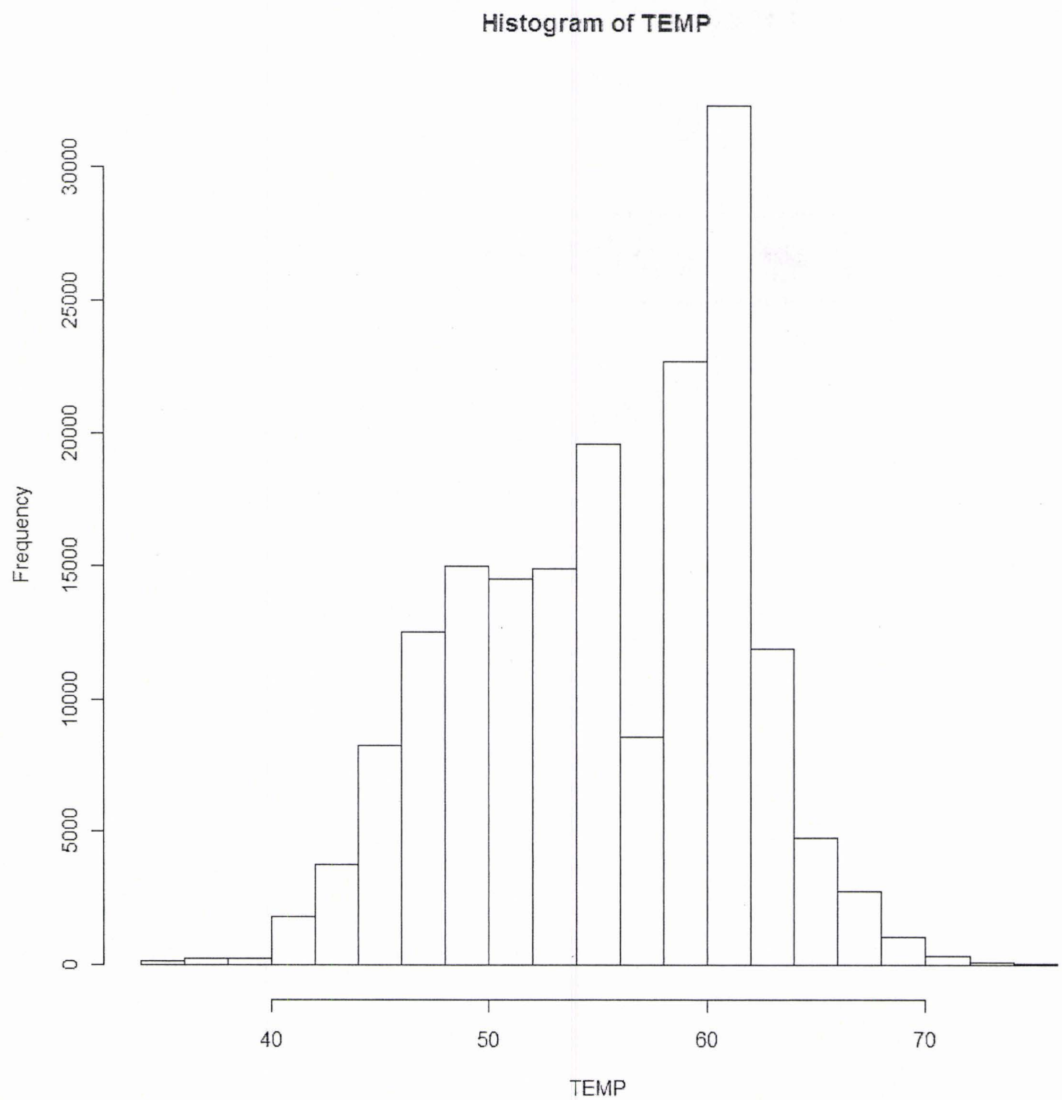
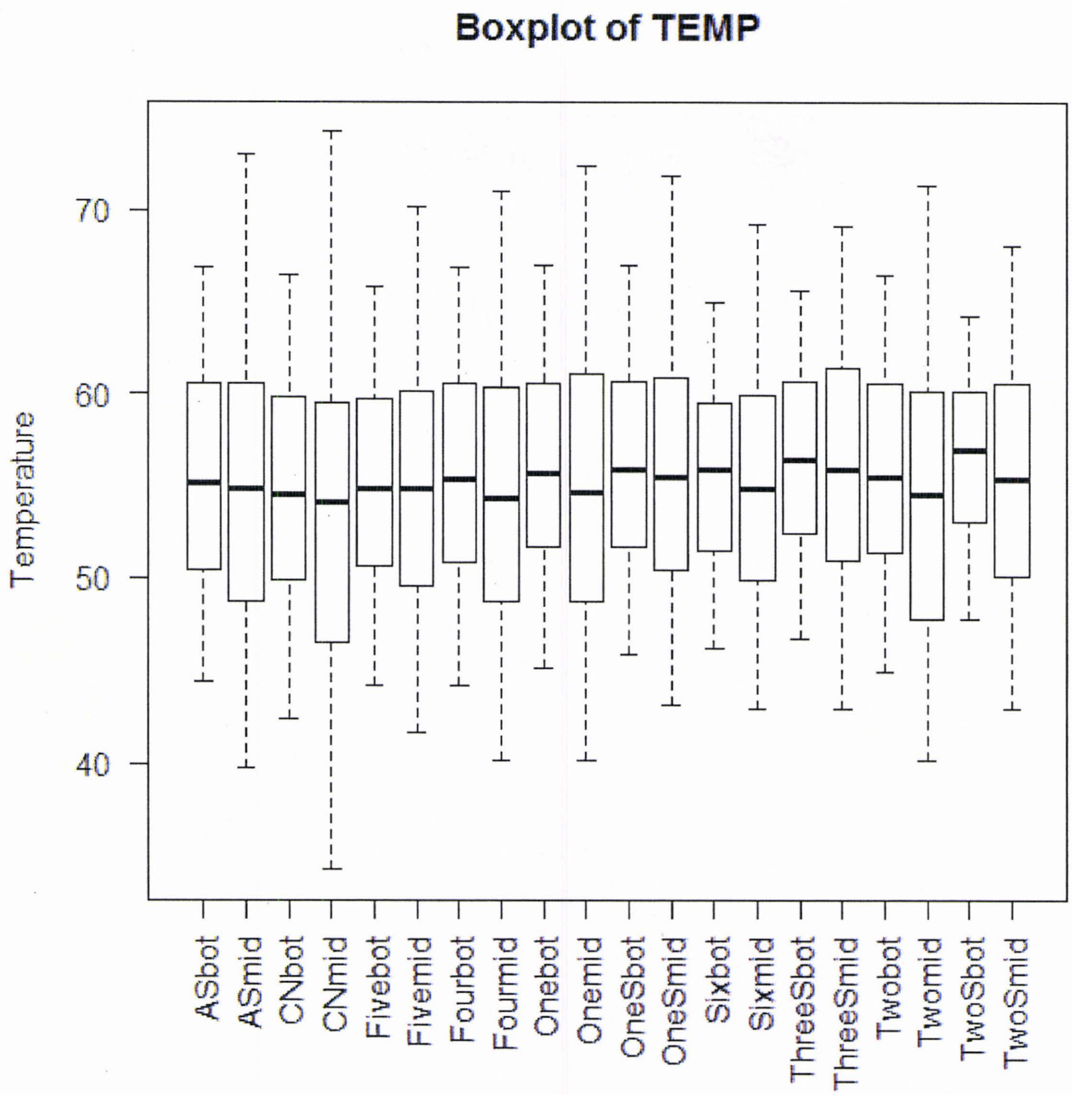
ANOVA Analysis

```
> work <- read.csv("FALL_BOTMID.txt")
> attach(work)
> hist(TEMP)
```




```
> boxplot(TEMP ~ LOGGER,main="Boxplot of TEMP", ylab="Temperature",las=2)
```




```
> Onebot<-TEMP[LOGGER=="Onebot"]
> Onemid<-TEMP[LOGGER=="Onemid"]
> Twobot<-TEMP[LOGGER=="Twobot"]
> Twomid<-TEMP[LOGGER=="Twomid"]
> Fourbot<-TEMP[LOGGER=="Fourbot"]
> Fourmid<-TEMP[LOGGER=="Fourmid"]
> Fivebot<-TEMP[LOGGER=="Fivebot"]
> Fivemid<-TEMP[LOGGER=="Fivemid"]
> Sixbot<-TEMP[LOGGER=="Sixbot"]
> Sixmid<-TEMP[LOGGER=="Sixmid"]
> OneSbot<-TEMP[LOGGER=="OneSbot"]
> OneSmid<-TEMP[LOGGER=="OneSmid"]
> TwoSbot<-TEMP[LOGGER=="TwoSbot"]
> TwoSmid<-TEMP[LOGGER=="TwoSmid"]
> ThreeSbot<-TEMP[LOGGER=="ThreeSbot"]
```

```
> ThreeSmid<-TEMP[LOGGER=="ThreeSmid"]
> ASbot<-TEMP[LOGGER=="ASbot"]
> ASmid<-TEMP[LOGGER=="ASmid"]
> CNbot<-TEMP[LOGGER=="CNbot"]
> CNmid<-TEMP[LOGGER=="CNmid"]
> var(Onebot); var(Onemid); var(Twobot); var(Twomid); var(Fourbot); var(Fourmid);
var(Fivebot); var(Fivemid);  var(Sixbot); var(Sixmid); var(OneSbot); var(OneSmid); var(TwoSbot);
var(TwoSmid); var(ThreeSbot); var(ThreeSmid); var(ASbot); var(ASmid); var(CNbot); var(CNmid);
[1] 31.28818
[1] 52.1644
[1] 32.00356
[1] 51.65547
[1] 34.37224
[1] 50.15681
[1] 30.88215
[1] 43.03853
[1] 24.90768
[1] 36.99531
[1] 30.14145
[1] 40.9202
[1] 20.45460
[1] 39.20385
[1] 26.48411
[1] 41.41495
[1] 34.21813
[1] 50.89247
[1] 36.69423
[1] 63.00635
> TEMP <- aov(TEMP~LOGGER)
> summary(TEMP)
             Df  Sum Sq Mean Sq F value    Pr(>F)
LOGGER        19  152294  8015.5  207.95 < 2.2e-16 ***
Residuals  175560 6766913    38.5
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Tukey's Test

```
> TEMP.mcp <- TukeyHSD(TEMP, "LOGGER")
> TEMP.mcp
  Tukey multiple comparisons of means
    95% family-wise confidence level

Fit: aov(formula = TEMP ~ LOGGER)
```

Logger	diff	lwr	upr	p
ASmid-ASbot	-1.1574914	-1.49E+00	-0.825410352	0
CNbot-ASbot	-0.95763481	-1.29E+00	-0.625553763	0
CNmid-ASbot	-2.662652466	-2.99E+00	-2.330571418	0
Fivebot-ASbot	-0.446462012	-7.79E-01	-0.114380964	0.0003364
Fivemid-ASbot	-0.953272582	-1.29E+00	-0.621191534	0
Fourbot-ASbot	0.057495728	-2.75E-01	0.389576776	1
Fourmid-ASbot	-1.42963071	-1.76E+00	-1.097549662	0
Onebot-ASbot	0.620557808	2.88E-01	0.952638856	0
Onemid-ASbot	-0.998412006	-1.33E+00	-0.666330958	0
OneSbot-ASbot	0.669615218	3.38E-01	1.001696266	0
OneSmid-ASbot	-0.127241144	-4.59E-01	0.204839904	0.9986288
Sixbot-ASbot	0.167451874	-1.65E-01	0.499532922	0.9655289
Sixmid-ASbot	-0.755055815	-1.09E+00	-0.422974767	0
ThreeSbot-ASbot	0.944463037	6.12E-01	1.276544085	0
ThreeSmid-ASbot	0.332126894	4.58E-05	0.664207942	0.0499202
Twobot-ASbot	0.318000342	-1.41E-02	0.65008139	0.0802235
Twomid-ASbot	-1.620507005	-1.95E+00	-1.288425958	0
TwoSbot-ASbot	1.067233854	7.35E-01	1.399314901	0
TwoSmid-ASbot	-0.618888028	-9.51E-01	-0.28680698	0
CNbot-ASmid	0.19985659	-1.32E-01	0.531937637	0.8400553
CNmid-ASmid	-1.505161066	-1.84E+00	-1.173080018	0
Fivebot-ASmid	0.711029388	3.79E-01	1.043110436	0
Fivemid-ASmid	0.204218818	-1.28E-01	0.536299865	0.8134307
Fourbot-ASmid	1.214987128	8.83E-01	1.547068176	0
Fourmid-ASmid	-0.27213931	-6.04E-01	0.059941738	0.2869734
Onebot-ASmid	1.778049208	1.45E+00	2.110130256	0
Onemid-ASmid	0.159079394	-1.73E-01	0.491160442	0.9797229
OneSbot-ASmid	1.827106618	1.50E+00	2.159187666	0
OneSmid-ASmid	1.030250256	6.98E-01	1.362331304	0
Sixbot-ASmid	1.324943274	9.93E-01	1.657024322	0
Sixmid-ASmid	0.402435585	7.04E-02	0.734516633	0.0028869
ThreeSbot-ASmid	2.101954437	1.77E+00	2.434035485	0
ThreeSmid-ASmid	1.489618294	1.16E+00	1.821699341	0
Twobot-ASmid	1.475491742	1.14E+00	1.807572789	0
Twomid-ASmid	-0.463015605	-7.95E-01	-0.130934558	0.0001404
TwoSbot-ASmid	2.224725253	1.89E+00	2.556806301	0
TwoSmid-ASmid	0.538603372	2.07E-01	0.87068442	0.0000017
CNmid-CNbot	-1.705017656	-2.04E+00	-1.372936608	0
Fivebot-CNbot	0.511172799	1.79E-01	0.843253847	0.0000091
Fivemid-CNbot	0.004362228	-3.28E-01	0.336443276	1

Fourbot-CNbot	1.015130539	6.83E-01	1.347211587	0
Fourmid-CNbot	-0.471995899	-8.04E-01	-0.139914851	0.0000862
Onebot-CNbot	1.578192619	1.25E+00	1.910273667	0
Onemid-CNbot	-0.040777196	-3.73E-01	0.291303852	1
OneSbot-CNbot	1.627250028	1.30E+00	1.959331076	0
OneSmid-CNbot	0.830393667	4.98E-01	1.162474715	0
Sixbot-CNbot	1.125086684	7.93E-01	1.457167732	0
Sixmid-CNbot	0.202578995	-1.30E-01	0.534660043	0.8236998
ThreeSbot-CNbot	1.902097847	1.57E+00	2.234178895	0
ThreeSmid-CNbot	1.289761704	9.58E-01	1.621842752	0
Twobot-CNbot	1.275635152	9.44E-01	1.6077162	0
Twomid-CNbot	-0.662872195	-9.95E-01	-0.330791147	0
TwoSbot-CNbot	2.024868664	1.69E+00	2.356949712	0
TwoSmid-CNbot	0.338746782	6.67E-03	0.67082783	0.0394864
Fivebot-CNmid	2.216190454	1.88E+00	2.548271502	0
Fivemid-CNmid	1.709379884	1.38E+00	2.041460932	0
Fourbot-CNmid	2.720148195	2.39E+00	3.052229242	0
Fourmid-CNmid	1.233021756	9.01E-01	1.565102804	0
Onebot-CNmid	3.283210275	2.95E+00	3.615291322	0
Onemid-CNmid	1.66424046	1.33E+00	1.996321508	0
OneSbot-CNmid	3.332267684	3.00E+00	3.664348732	0
OneSmid-CNmid	2.535411322	2.20E+00	2.86749237	0
Sixbot-CNmid	2.83010434	2.50E+00	3.162185388	0
Sixmid-CNmid	1.907596651	1.58E+00	2.239677699	0
ThreeSbot-CNmid	3.607115503	3.28E+00	3.939196551	0
ThreeSmid-CNmid	2.99477936	2.66E+00	3.326860408	0
Twobot-CNmid	2.980652808	2.65E+00	3.312733856	0
Twomid-CNmid	1.042145461	7.10E-01	1.374226509	0
TwoSbot-CNmid	3.72988632	3.40E+00	4.061967367	0
TwoSmid-CNmid	2.043764438	1.71E+00	2.375845486	0
Fivemid-Fivebot	-0.506810571	-8.39E-01	-0.174729523	0.0000118
Fourbot-Fivebot	0.50395774	1.72E-01	0.836038788	0.000014
Fourmid-Fivebot	-0.983168698	-1.32E+00	-0.65108765	0
Onebot-Fivebot	1.06701982	7.35E-01	1.399100868	0
Onemid-Fivebot	-0.551949994	-8.84E-01	-0.219868946	0.0000007
OneSbot-Fivebot	1.11607723	7.84E-01	1.448158278	0
OneSmid-Fivebot	0.319220868	-1.29E-02	0.651301916	0.0771121
Sixbot-Fivebot	0.613913885	2.82E-01	0.945994933	0
Sixmid-Fivebot	-0.308593803	-6.41E-01	0.023487244	0.1078059
ThreeSbot-Fivebot	1.390925048	1.06E+00	1.723006096	0
ThreeSmid-Fivebot	0.778588905	4.47E-01	1.110669953	0

Twobot-Fivebot	0.764462353	4.32E-01	1.096543401	0
Twomid-Fivebot	-1.174044994	-1.51E+00	-0.841963946	0
TwoSbot-Fivebot	1.513695865	1.18E+00	1.845776913	0
TwoSmid-Fivebot	-0.172426017	-5.05E-01	0.159655031	0.9541017
Fourbot-Fivemid	1.010768311	6.79E-01	1.342849359	0
Fourmid-Fivemid	-0.476358127	-8.08E-01	-0.14427708	0.0000677
Onebot-Fivemid	1.573830391	1.24E+00	1.905911439	0
Onemid-Fivemid	-0.045139424	-3.77E-01	0.286941624	1
OneSbot-Fivemid	1.6228878	1.29E+00	1.954968848	0
OneSmid-Fivemid	0.826031439	4.94E-01	1.158112487	0
Sixbot-Fivemid	1.120724456	7.89E-01	1.452805504	0
Sixmid-Fivemid	0.198216767	-1.34E-01	0.530297815	0.8494787
ThreeSbot-Fivemid	1.897735619	1.57E+00	2.229816667	0
ThreeSmid-Fivemid	1.285399476	9.53E-01	1.617480524	0
Twobot-Fivemid	1.271272924	9.39E-01	1.603353972	0
Twomid-Fivemid	-0.667234423	-9.99E-01	-0.335153375	0
TwoSbot-Fivemid	2.020506436	1.69E+00	2.352587484	0
TwoSmid-Fivemid	0.334384554	2.30E-03	0.666465602	0.0461232
Fourmid-Fourbot	-1.487126438	-1.82E+00	-1.15504539	0
Onebot-Fourbot	0.56306208	2.31E-01	0.895143128	0.0000004
Onemid-Fourbot	-1.055907734	-1.39E+00	-0.723826687	0
OneSbot-Fourbot	0.61211949	2.80E-01	0.944200538	0
OneSmid-Fourbot	-0.184736872	-5.17E-01	0.147344176	0.9142662
Sixbot-Fourbot	0.109956145	-2.22E-01	0.442037193	0.999822
Sixmid-Fourbot	-0.812551543	-1.14E+00	-0.480470496	0
ThreeSbot-Fourbot	0.886967308	5.55E-01	1.219048356	0
ThreeSmid-Fourbot	0.274631165	-5.74E-02	0.606712213	0.2707882
Twobot-Fourbot	0.260504613	-7.16E-02	0.592585661	0.3695518
Twomid-Fourbot	-1.678002734	-2.01E+00	-1.345921686	0
TwoSbot-Fourbot	1.009738125	6.78E-01	1.341819173	0
TwoSmid-Fourbot	-0.676383757	-1.01E+00	-0.344302709	0
Onebot-Fourmid	2.050188518	1.72E+00	2.382269566	0
Onemid-Fourmid	0.431218704	9.91E-02	0.763299752	0.0007291
OneSbot-Fourmid	2.099245928	1.77E+00	2.431326976	0
OneSmid-Fourmid	1.302389566	9.70E-01	1.634470614	0
Sixbot-Fourmid	1.597082583	1.27E+00	1.929163631	0
Sixmid-Fourmid	0.674574895	3.42E-01	1.006655942	0
ThreeSbot-Fourmid	2.374093746	2.04E+00	2.706174794	0
ThreeSmid-Fourmid	1.761757603	1.43E+00	2.093838651	0
Twobot-Fourmid	1.747631051	1.42E+00	2.079712099	0
Twomid-Fourmid	-0.190876296	-5.23E-01	0.141204752	0.8875855

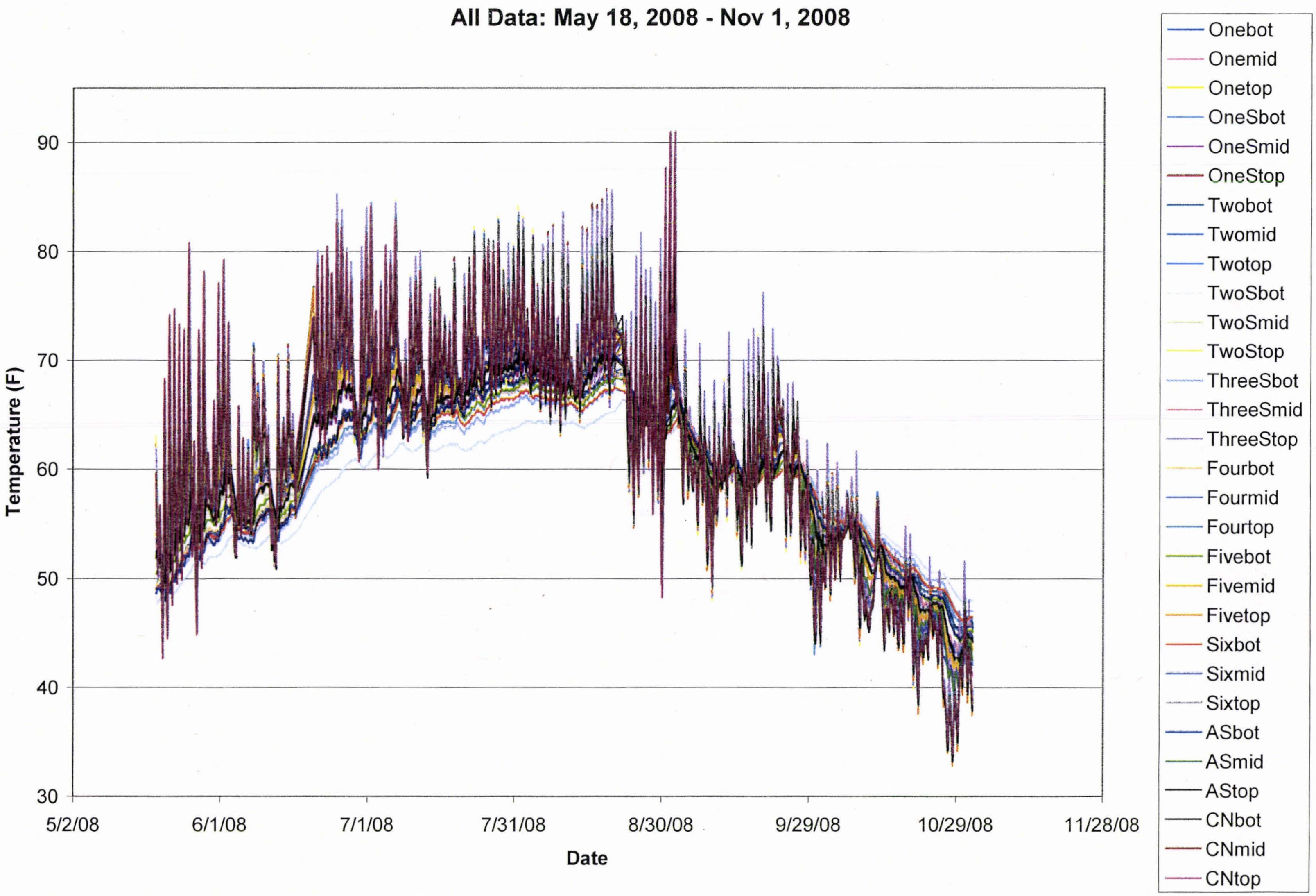
TwoSbot-Fourmid	2.496864563	2.16E+00	2.828945611	0
TwoSmid-Fourmid	0.810742681	4.79E-01	1.142823729	0
Onemid-Onebot	-1.618969814	-1.95E+00	-1.286888766	0
OneSbot-Onebot	0.04905741	-2.83E-01	0.381138458	1
OneSmid-Onebot	-0.747798952	-1.08E+00	-0.415717904	0
Sixbot-Onebot	-0.453105935	-7.85E-01	-0.121024887	0.0002379
Sixmid-Onebot	-1.375613623	-1.71E+00	-1.043532576	0
ThreeSbot-Onebot	0.323905228	-8.18E-03	0.655986276	0.0660824
ThreeSmid-Onebot	-0.288430915	-6.21E-01	0.043650133	0.1916598
Twobot-Onebot	-0.302557467	-6.35E-01	0.029523581	0.1291609
Twomid-Onebot	-2.241064814	-2.57E+00	-1.908983766	0
TwoSbot-Onebot	0.446676045	1.15E-01	0.778757093	0.0003327
TwoSmid-Onebot	-1.239445837	-1.57E+00	-0.907364789	0
OneSbot-Onemid	1.668027224	1.34E+00	2.000108272	0
OneSmid-Onemid	0.871170862	5.39E-01	1.20325191	0
Sixbot-Onemid	1.16586388	8.34E-01	1.497944928	0
Sixmid-Onemid	0.243356191	-8.87E-02	0.575437239	0.507339
ThreeSbot-Onemid	1.942875043	1.61E+00	2.274956091	0
ThreeSmid-Onemid	1.3305389	9.98E-01	1.662619947	0
Twobot-Onemid	1.316412348	9.84E-01	1.648493395	0
Twomid-Onemid	-0.622094999	-9.54E-01	-0.290013952	0
TwoSbot-Onemid	2.065645859	1.73E+00	2.397726907	0
TwoSmid-Onemid	0.379523978	4.74E-02	0.711605026	0.007945
OneSmid-OneSbot	-0.796856362	-1.13E+00	-0.464775314	0
Sixbot-OneSbot	-0.502163344	-8.34E-01	-0.170082297	0.0000155
Sixmid-OneSbot	-1.424671033	-1.76E+00	-1.092589985	0
ThreeSbot-OneSbot	0.274847819	-5.72E-02	0.606928866	0.2694077
ThreeSmid-OneSbot	-0.337488324	-6.70E-01	-0.005407277	0.0413104
Twobot-OneSbot	-0.351614876	-6.84E-01	-0.019533829	0.024505
Twomid-OneSbot	-2.290122223	-2.62E+00	-1.958041176	0
TwoSbot-OneSbot	0.397618635	6.55E-02	0.729699683	0.0035942
TwoSmid-OneSbot	-1.288503246	-1.62E+00	-0.956422199	0
Sixbot-OneSmid	0.294693017	-3.74E-02	0.626774065	0.1617012
Sixmid-OneSmid	-0.627814671	-9.60E-01	-0.295733624	0
ThreeSbot-OneSmid	1.07170418	7.40E-01	1.403785228	0
ThreeSmid-OneSmid	0.459368037	1.27E-01	0.791449085	0.0001707
Twobot-OneSmid	0.445241485	1.13E-01	0.777322533	0.0003583
Twomid-OneSmid	-1.493265862	-1.83E+00	-1.161184814	0
TwoSbot-OneSmid	1.194474997	8.62E-01	1.526556045	0
TwoSmid-OneSmid	-0.491646885	-8.24E-01	-0.159565837	0.0000286
Sixmid-Sixbot	-0.922507689	-1.25E+00	-0.590426641	0

ThreeSbot-Sixbot	0.777011163	4.45E-01	1.109092211	0
ThreeSmid-Sixbot	0.16467502	-1.67E-01	0.496756068	0.970889
Twobot-Sixbot	0.150548468	-1.82E-01	0.482629516	0.9889755
Twomid-Sixbot	-1.787958879	-2.12E+00	-1.455877831	0
TwoSbot-Sixbot	0.89978198	5.68E-01	1.231863028	0
TwoSmid-Sixbot	-0.786339902	-1.12E+00	-0.454258854	0
ThreeSbot-Sixmid	1.699518852	1.37E+00	2.0315999	0
ThreeSmid-Sixmid	1.087182709	7.55E-01	1.419263757	0
Twobot-Sixmid	1.073056157	7.41E-01	1.405137205	0
Twomid-Sixmid	-0.86545119	-1.20E+00	-0.533370143	0
TwoSbot-Sixmid	1.822289669	1.49E+00	2.154370716	0
TwoSmid-Sixmid	0.136167787	-1.96E-01	0.468248835	0.9966997
ThreeSmid-ThreeSbot	-0.612336143	-9.44E-01	-0.280255095	0
Twobot-ThreeSbot	-0.626462695	-9.59E-01	-0.294381647	0
Twomid-ThreeSbot	-2.564970042	-2.90E+00	-2.232888994	0
TwoSbot-ThreeSbot	0.122770817	-2.09E-01	0.454851865	0.9991533
TwoSmid-ThreeSbot	-1.563351065	-1.90E+00	-1.231270017	0
Twobot-ThreeSmid	-0.014126552	-3.46E-01	0.317954496	1
Twomid-ThreeSmid	-1.952633899	-2.28E+00	-1.620552851	0
TwoSbot-ThreeSmid	0.73510696	4.03E-01	1.067188008	0
TwoSmid-ThreeSmid	-0.951014922	-1.28E+00	-0.618933874	0
Twomid-Twobot	-1.938507347	-2.27E+00	-1.606426299	0
TwoSbot-Twobot	0.749233512	4.17E-01	1.08131456	0
TwoSmid-Twobot	-0.93688837	-1.27E+00	-0.604807322	0
TwoSbot-Twomid	2.687740859	2.36E+00	3.019821907	0
TwoSmid-Twomid	1.001618977	6.70E-01	1.333700025	0
TwoSmid-TwoSbot	-1.686121882	-2.02E+00	-1.354040834	0

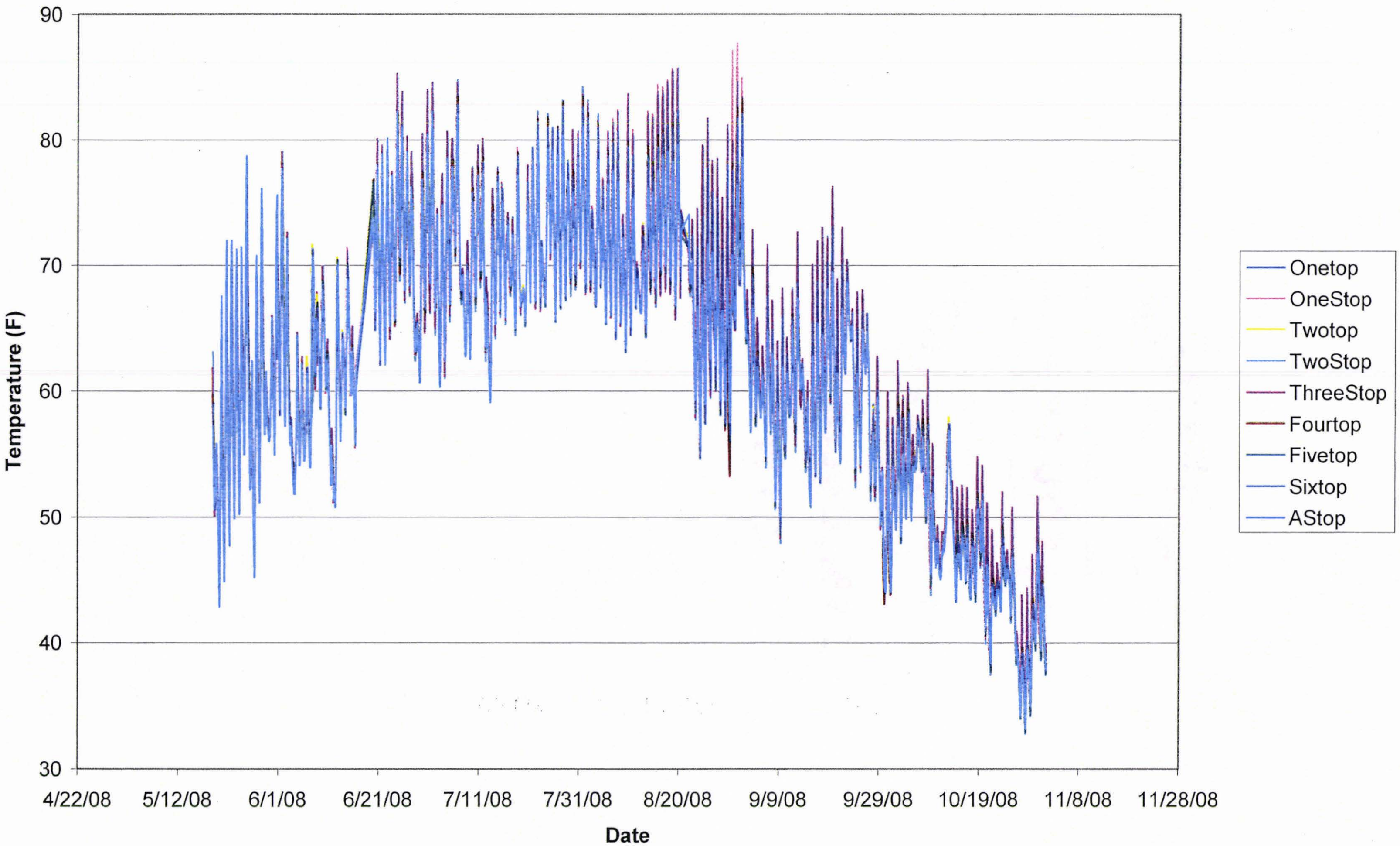
```
> plot(TEMP.mcp)
```

Appendix D

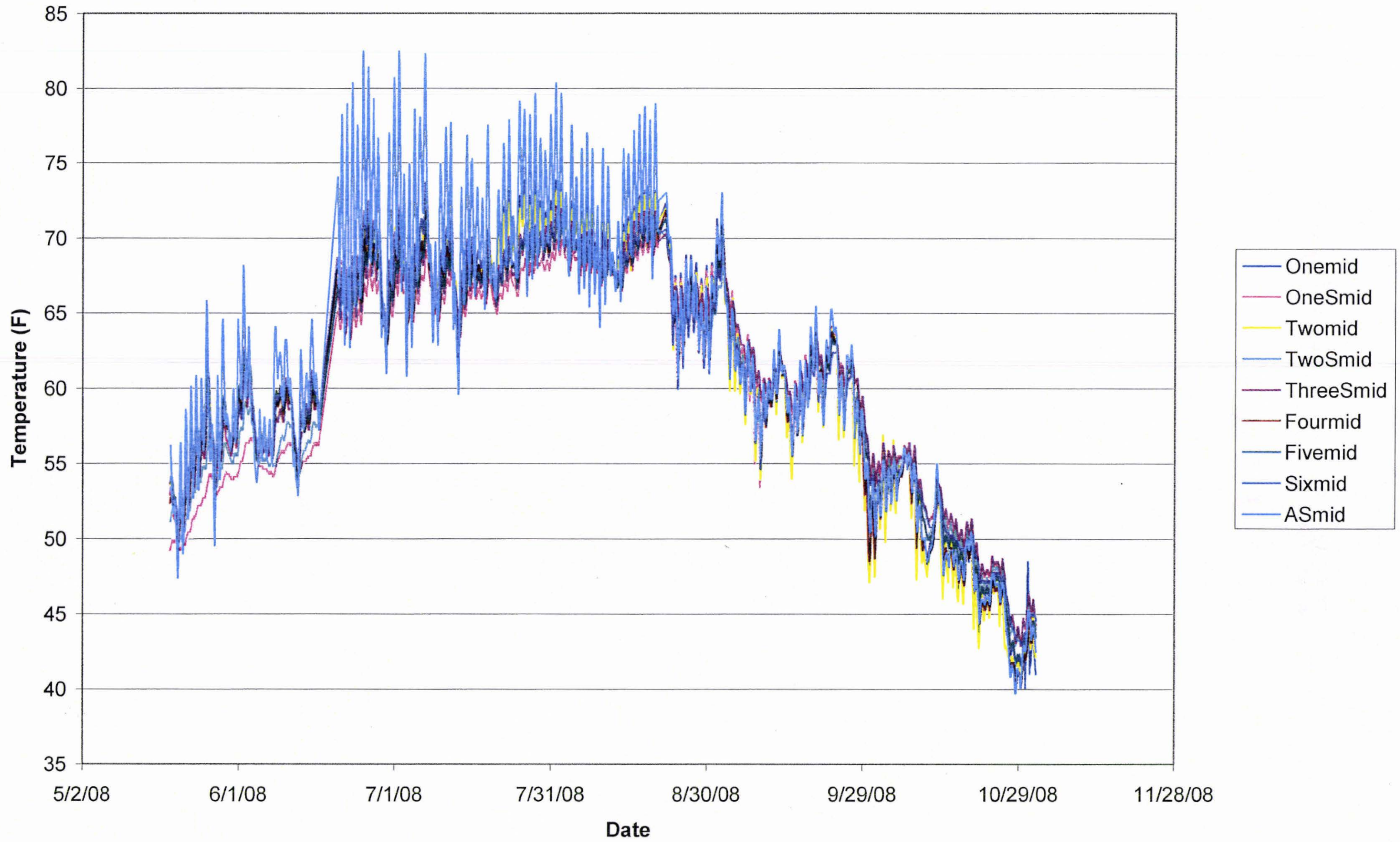
Temperature Profile Graphs – Full Data Set


All Data: May 18, 2008 - Nov 1, 2008
Temperature (F)
90
80
70
60
50
40
30
5/2/08
6/1/08
7/1/08
7/31/08
8/30/08
9/29/08
10/29/08
11/28/08
Date
Onebot
Onemid
Onetop
OneSbot
OneSmid
OneStop
Twobot
Twomid
Twotop
TwoSbot
TwoSmid
TwoStop
ThreeSbot
ThreeSmid
ThreeStop
Fourbot
Fourmid
Fourtop
Fivebot
Fivemid
Fivetop
Sixbot
Sixmid
Sixtop
ASbot
ASmid
AStop
CNbot
CNmid
CNtop

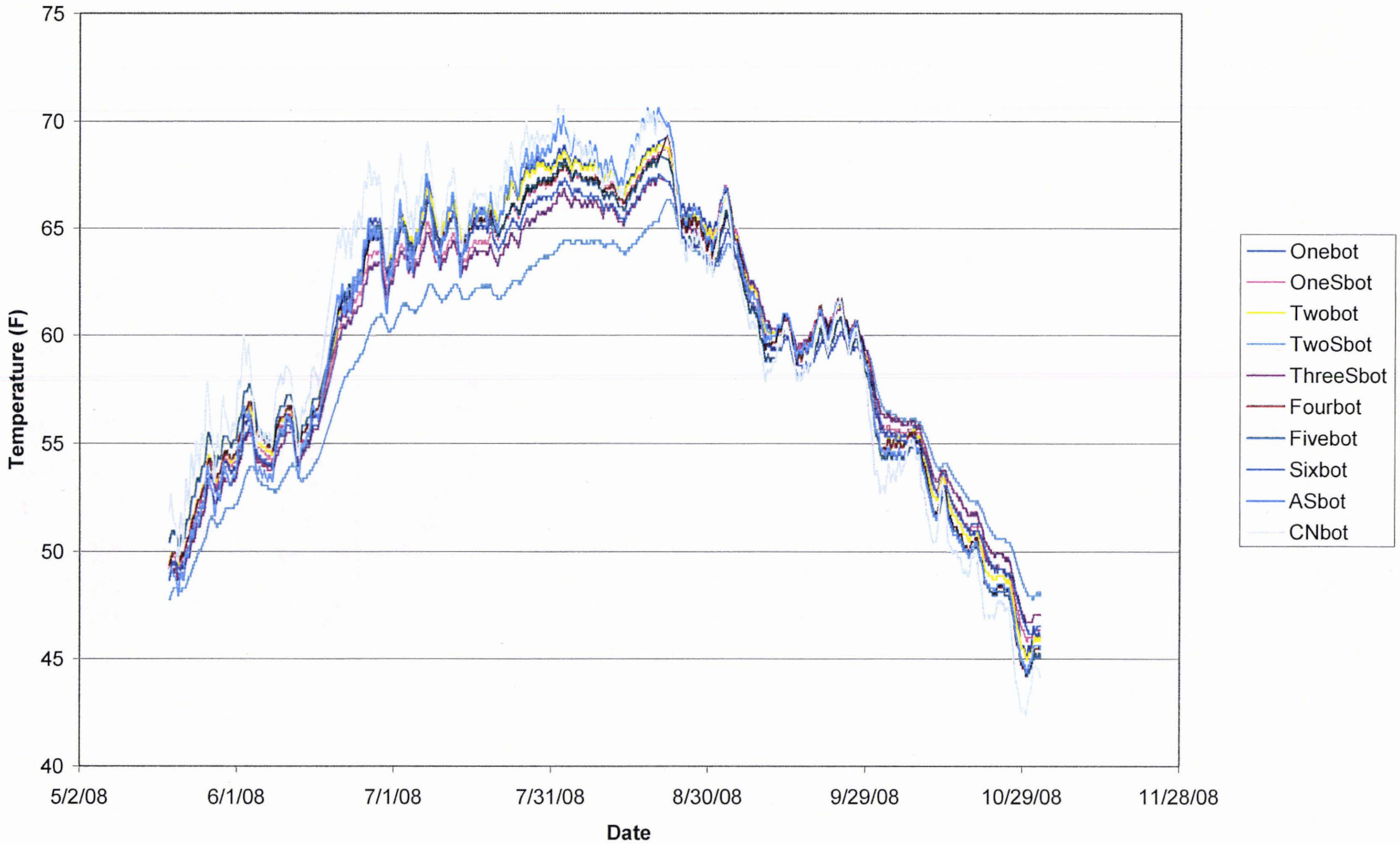
Top loggers: May 18, 2008 - Nov 1, 2008

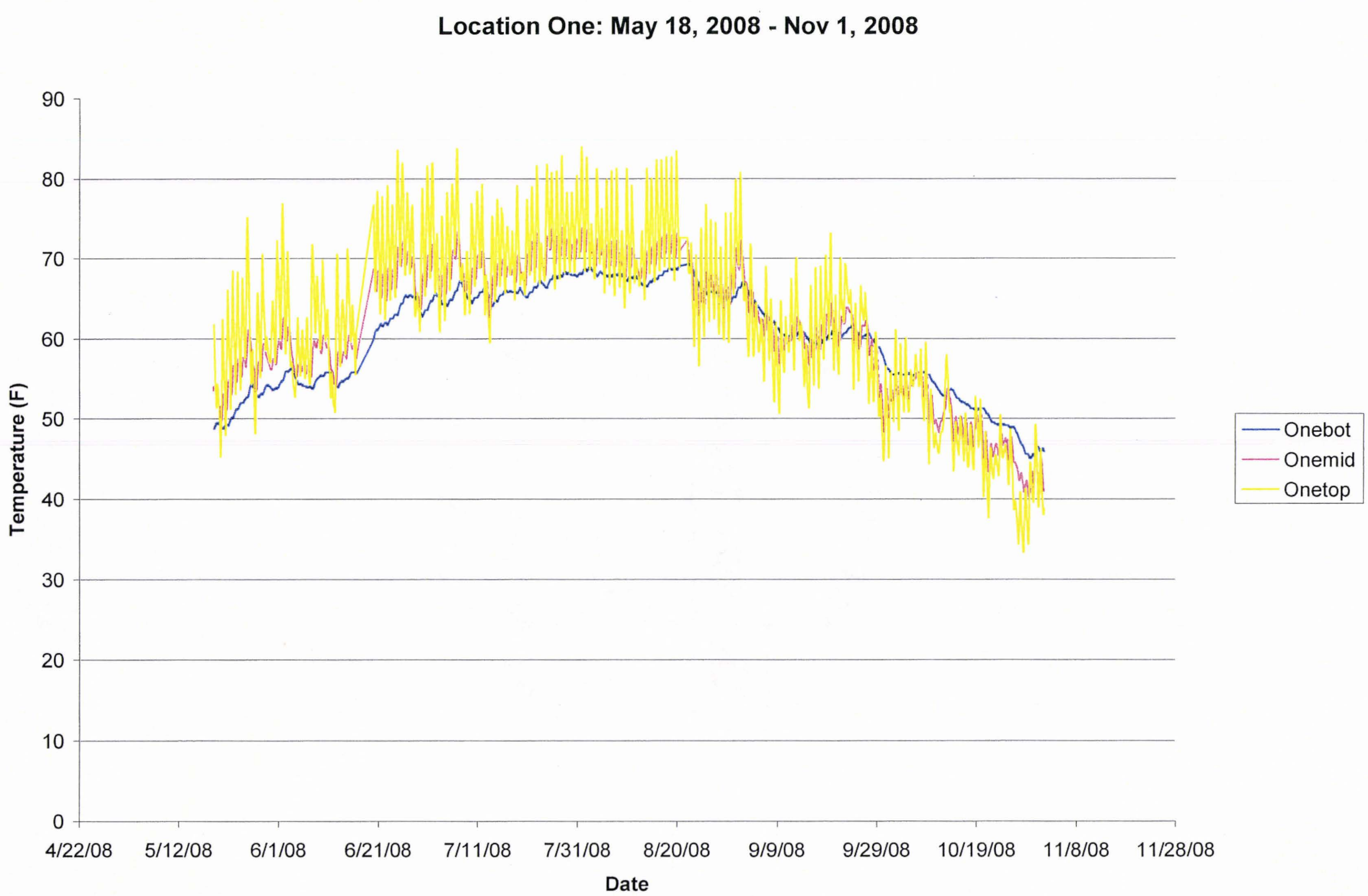


Middle Loggers: May 18, 2008 - Nov 1, 2008

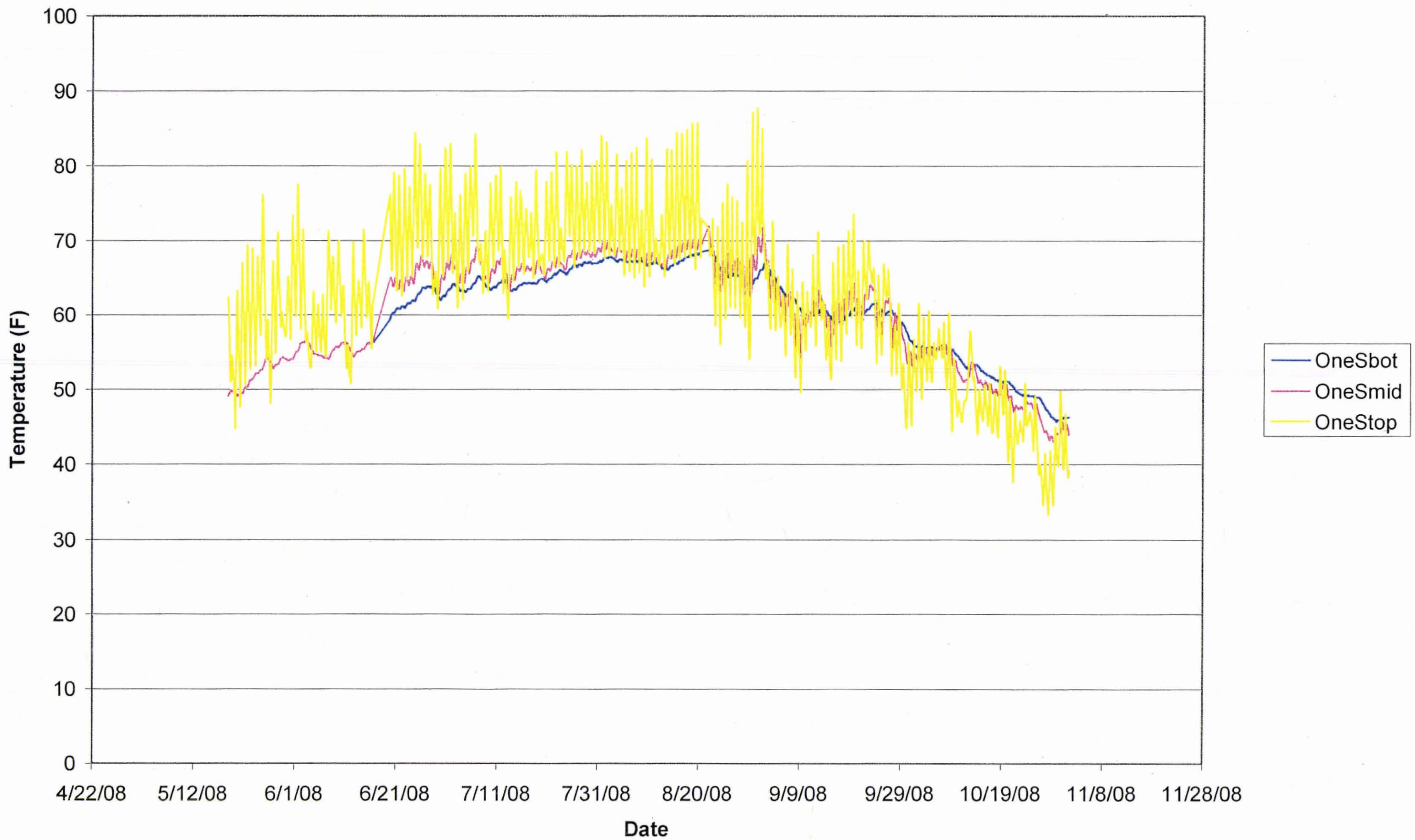


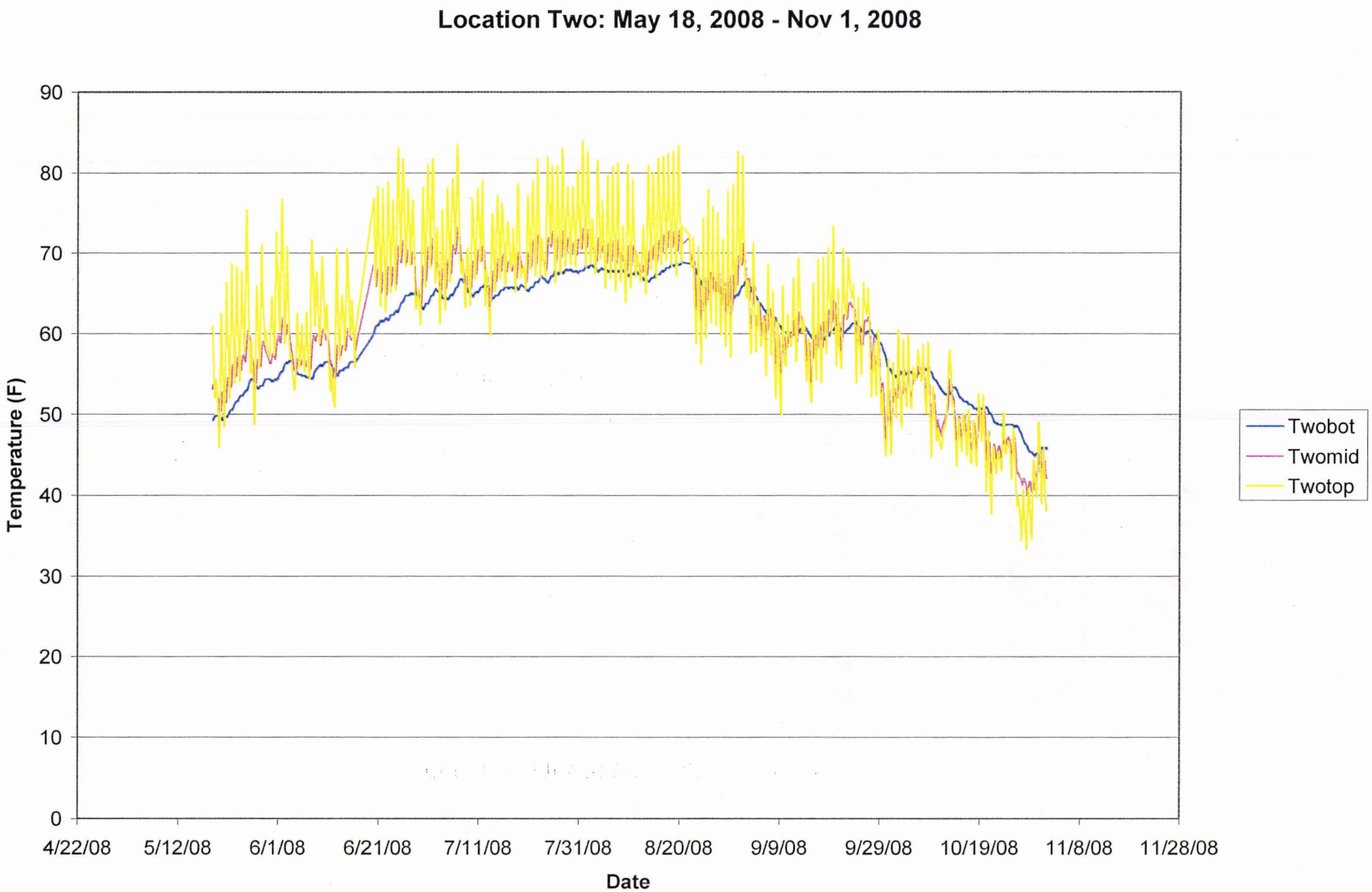
Bottom Loggers: May 18,2008 - Nov 1, 2008



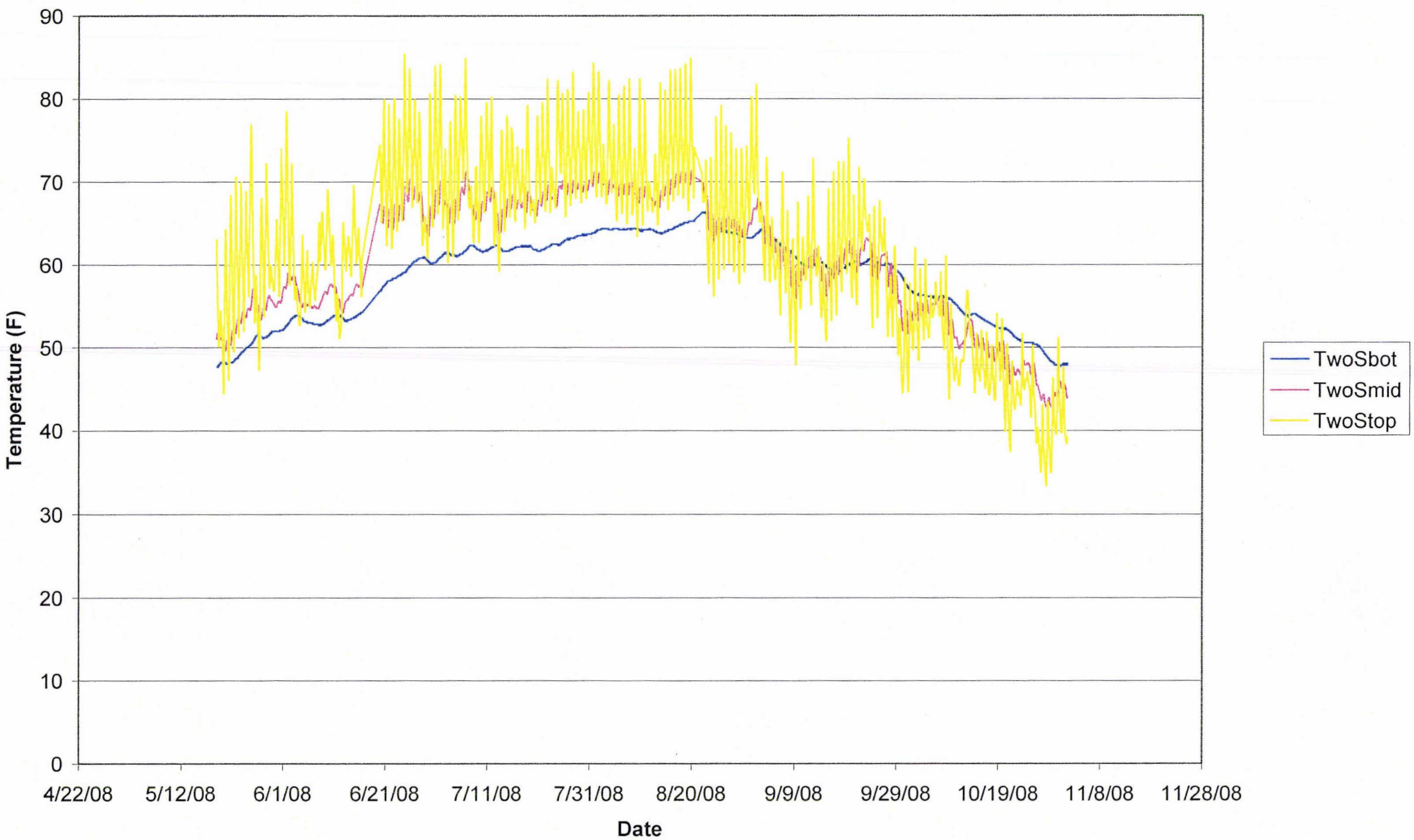

Location One: May 18, 2008 - Nov 1, 2008
Temperature (F)
0
10
20
30
40
50
60
70
80
90
Date
4/22/08
5/12/08
6/1/08
6/21/08
7/11/08
7/31/08
8/20/08
9/9/08
9/29/08
10/19/08
11/8/08
11/28/08
Onebot
Onemid
Onetop

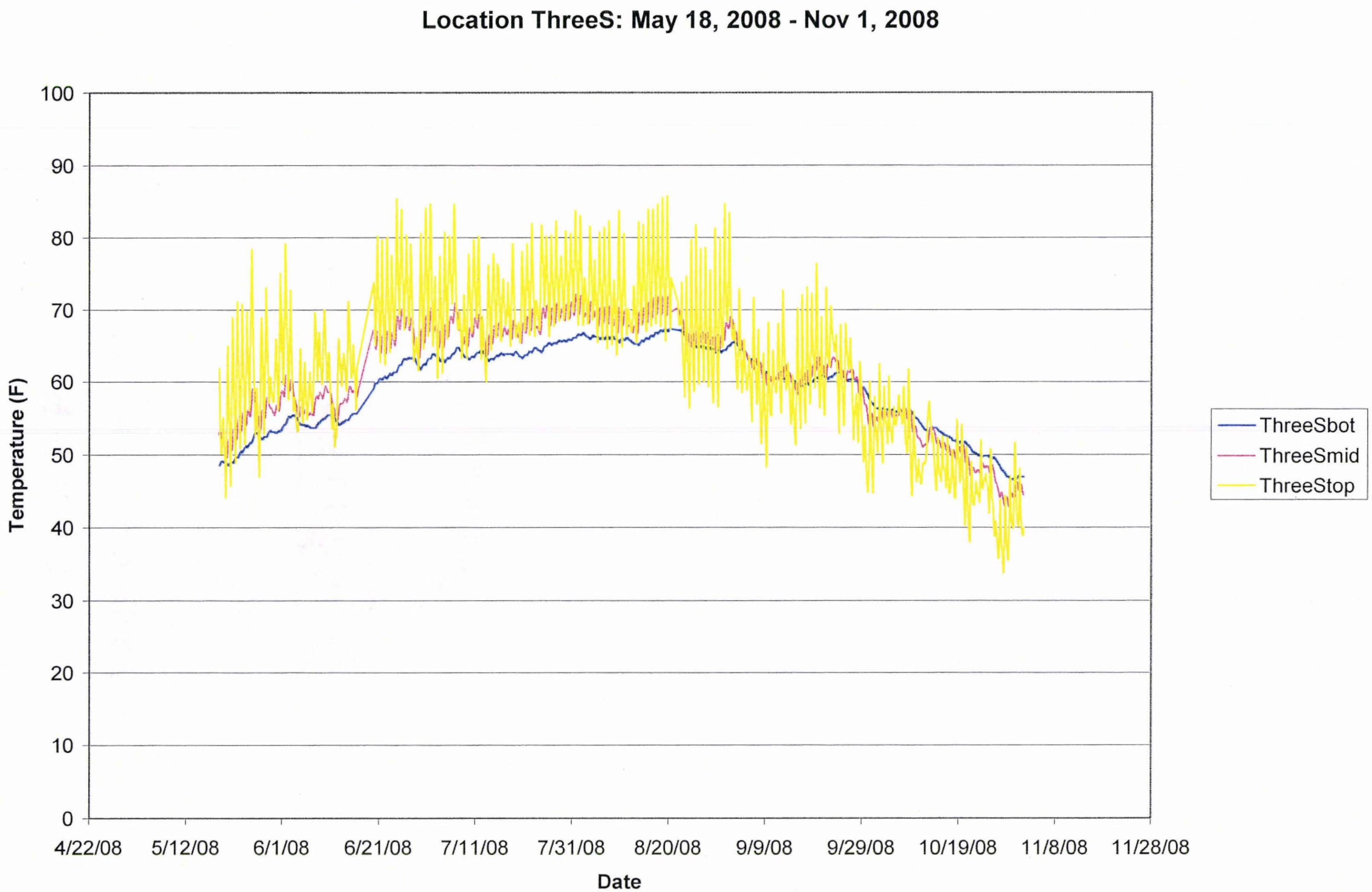
Location OneS: May 18, 2008 - Nov 1, 2008

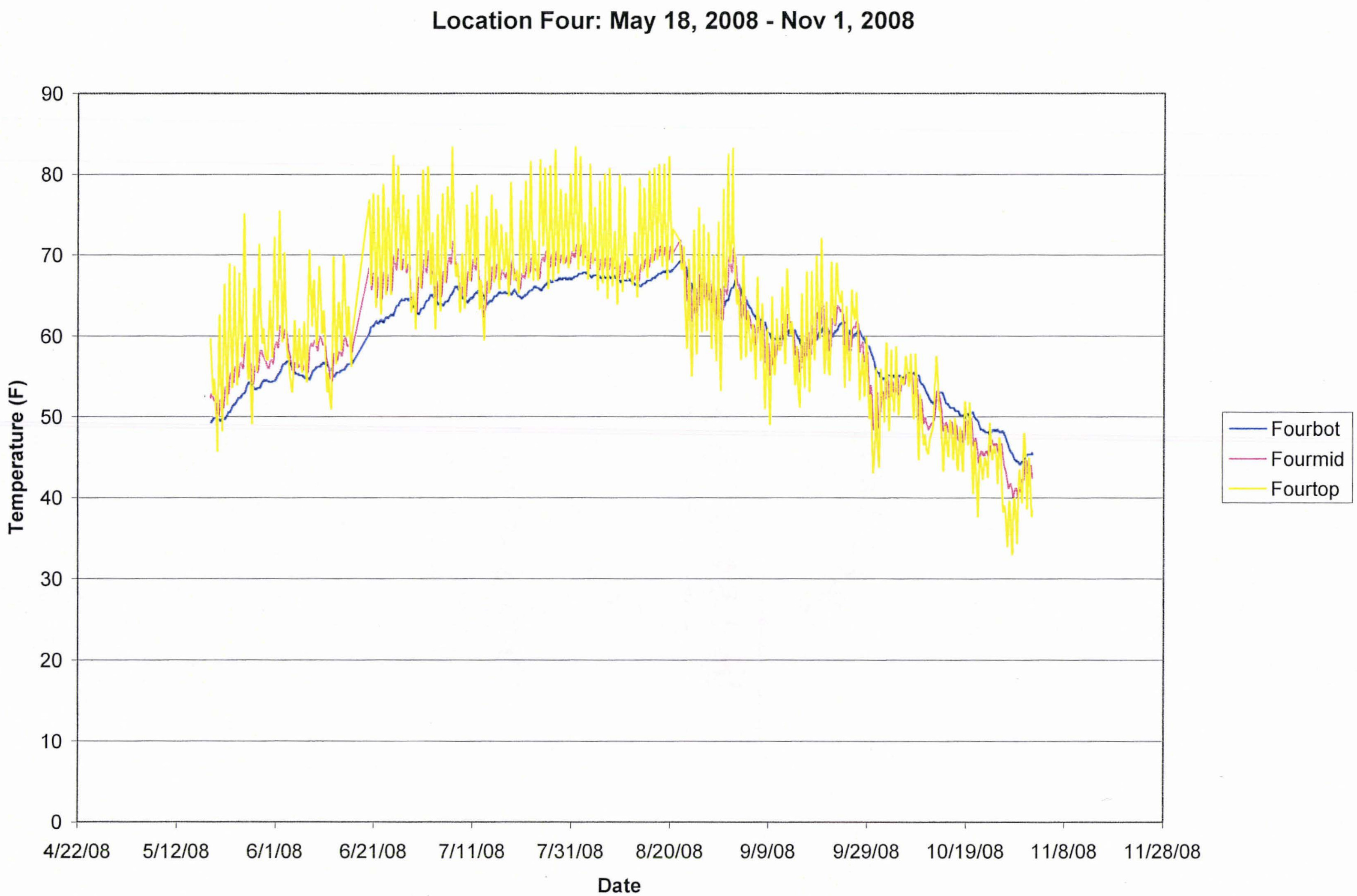



Location Two: May 18, 2008 - Nov 1, 2008
Temperature (F)
90
80
70
60
50
40
30
20
10
0
4/22/08
5/12/08
6/1/08
6/21/08
7/11/08
7/31/08
8/20/08
9/9/08
9/29/08
10/19/08
11/8/08
11/28/08
Date
Twobot
Twomid
Twotop

Location TwoS: May 18, 2008 - Nov 1, 2008

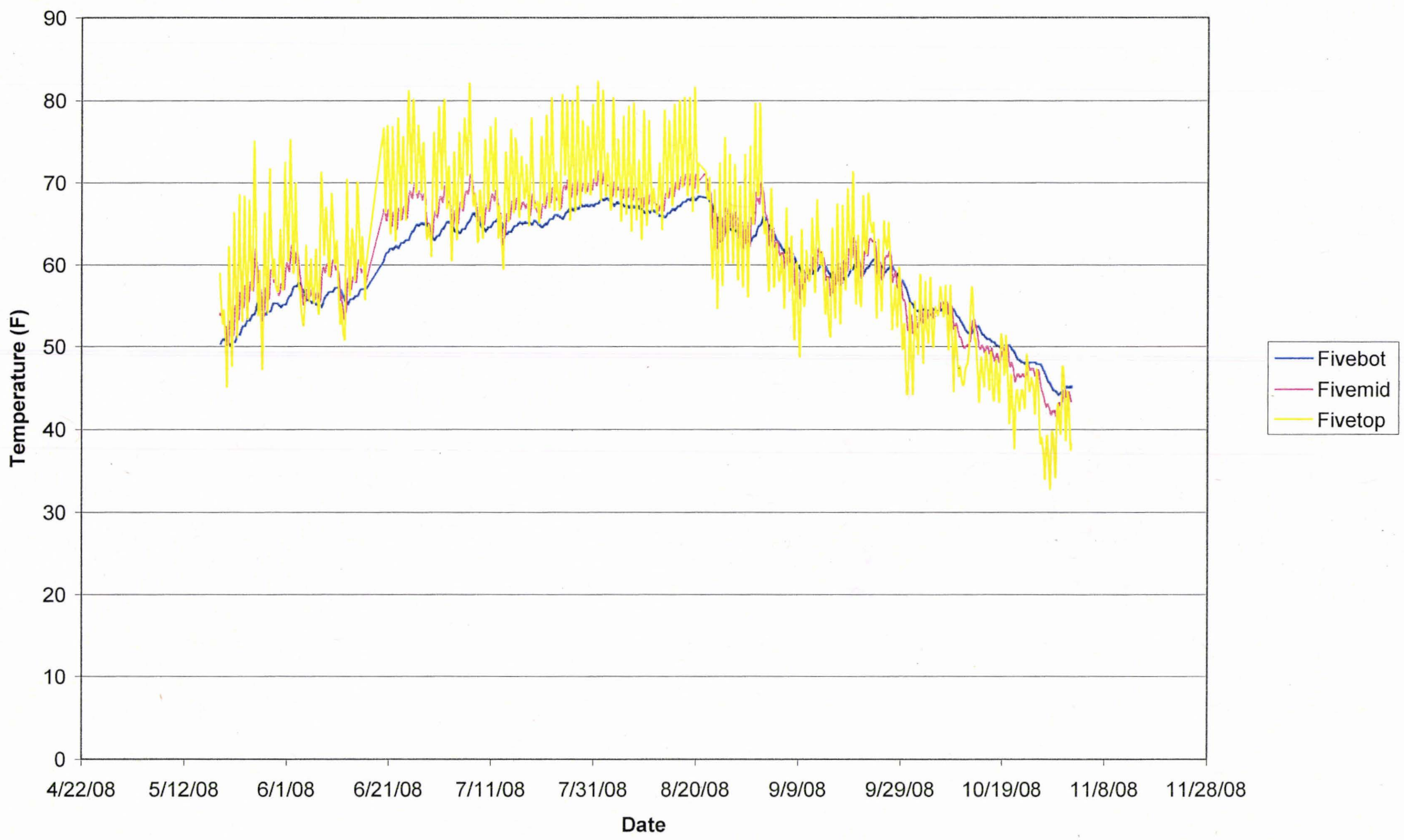


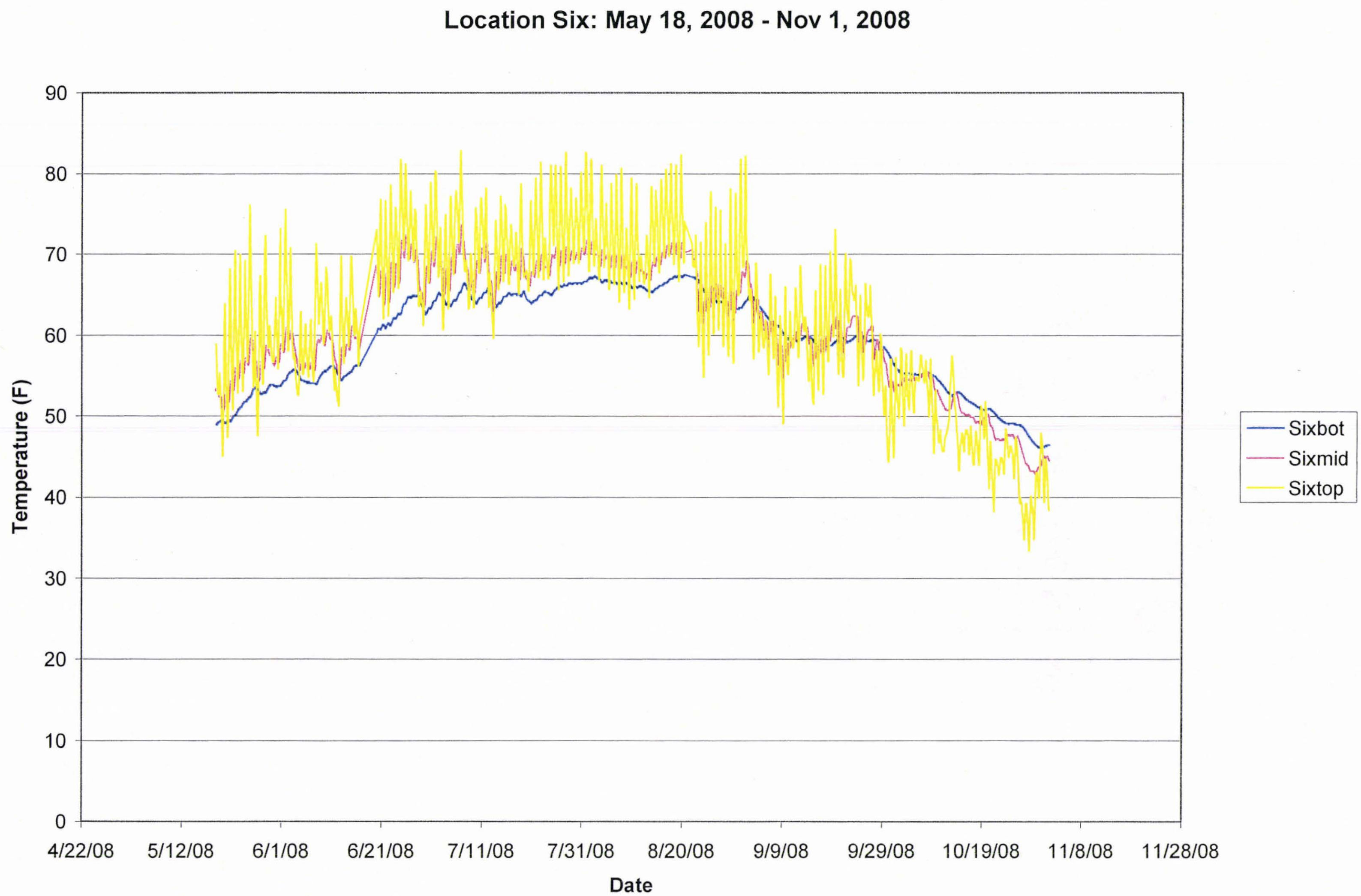

Location ThreeS: May 18, 2008 - Nov 1, 2008
Temperature (F)
Date
ThreeSbot
ThreeSmid
ThreeStop
100
90
80
70
60
50
40
30
20
10
0
4/22/08
5/12/08
6/1/08
6/21/08
7/11/08
7/31/08
8/20/08
9/9/08
9/29/08
10/19/08
11/8/08
11/28/08

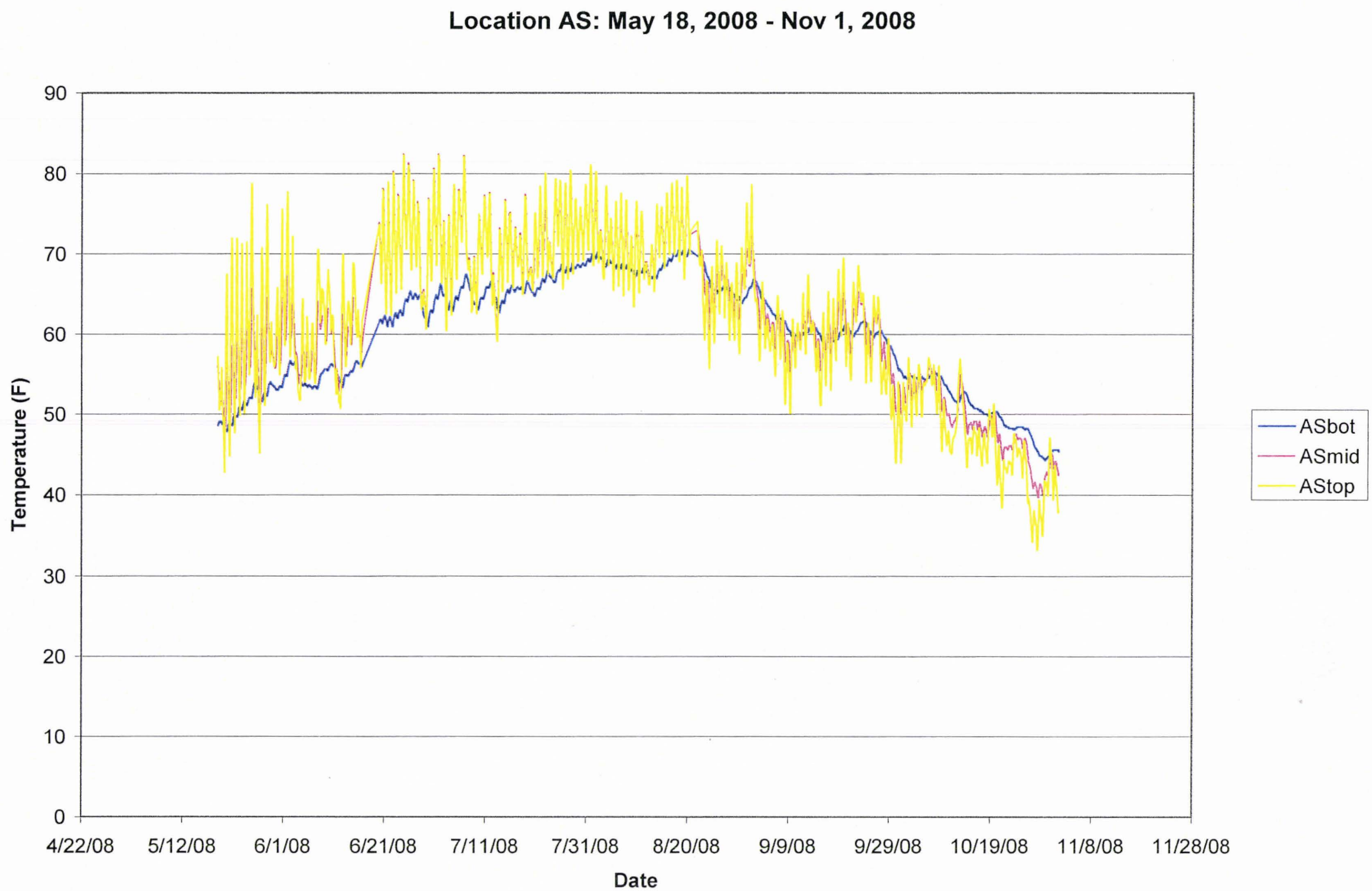


Location Four: May 18, 2008 - Nov 1, 2008
Temperature (F)
90
80
70
60
50
40
30
20
10
0
4/22/08
5/12/08
6/1/08
6/21/08
7/11/08
7/31/08
8/20/08
9/9/08
9/29/08
10/19/08
11/8/08
11/28/08
Date
Fourbot
Fourmid
Fourtop

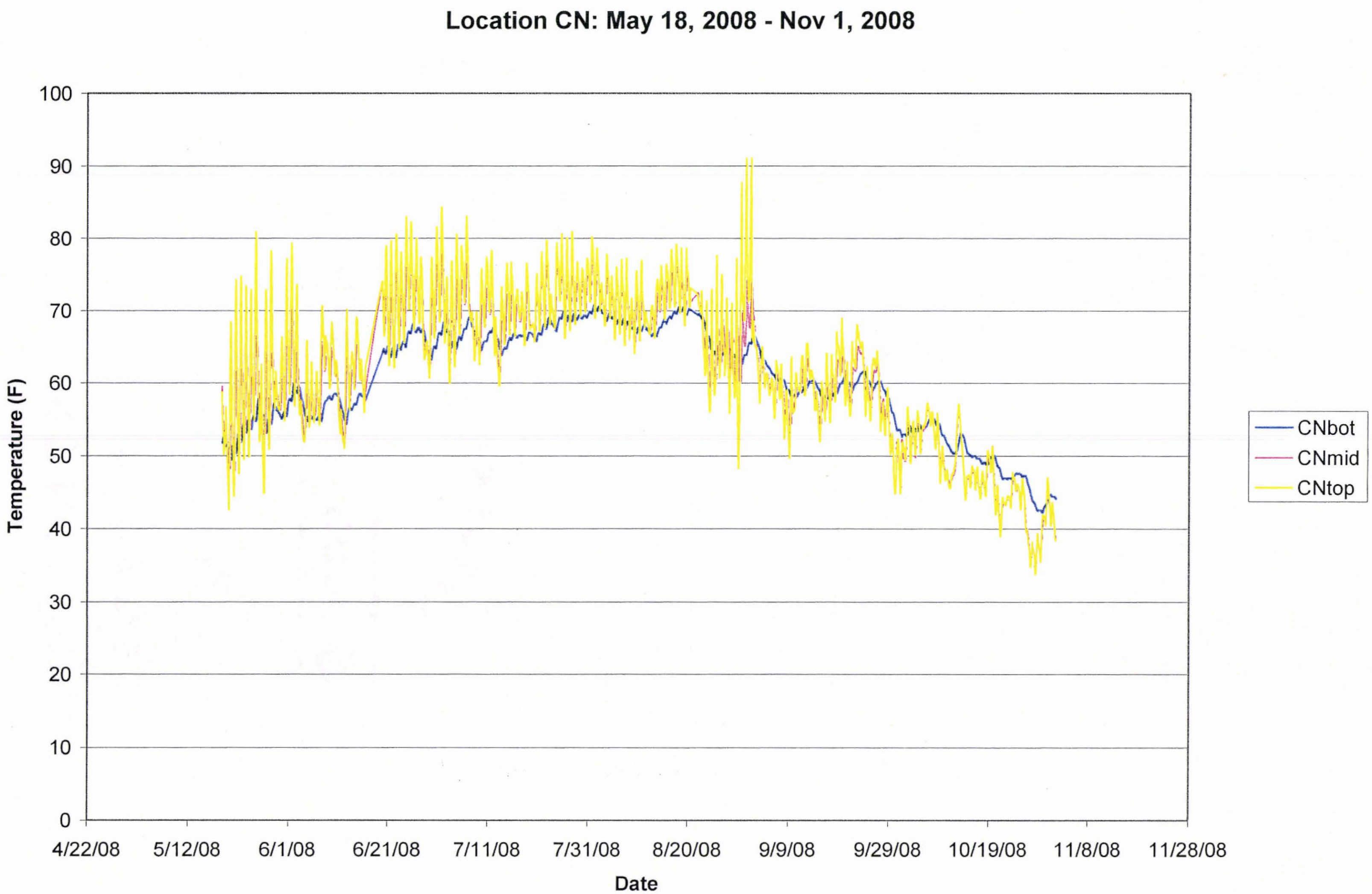
Location Five: May 18, 2008 - Nov 1, 2008




Location Six: May 18, 2008 - Nov 1, 2008
Temperature (F)
90
80
70
60
50
40
30
20
10
0
4/22/08
5/12/08
6/1/08
6/21/08
7/11/08
7/31/08
8/20/08
9/9/08
9/29/08
10/19/08
11/8/08
11/28/08
Date
Sixbot
Sixmid
Sixtop



Location AS: May 18, 2008 - Nov 1, 2008
Temperature (F)
90
80
70
60
50
40
30
20
10
0
4/22/08
5/12/08
6/1/08
6/21/08
7/11/08
7/31/08
8/20/08
9/9/08
9/29/08
10/19/08
11/8/08
11/28/08
Date
ASbot
ASmid
AStop

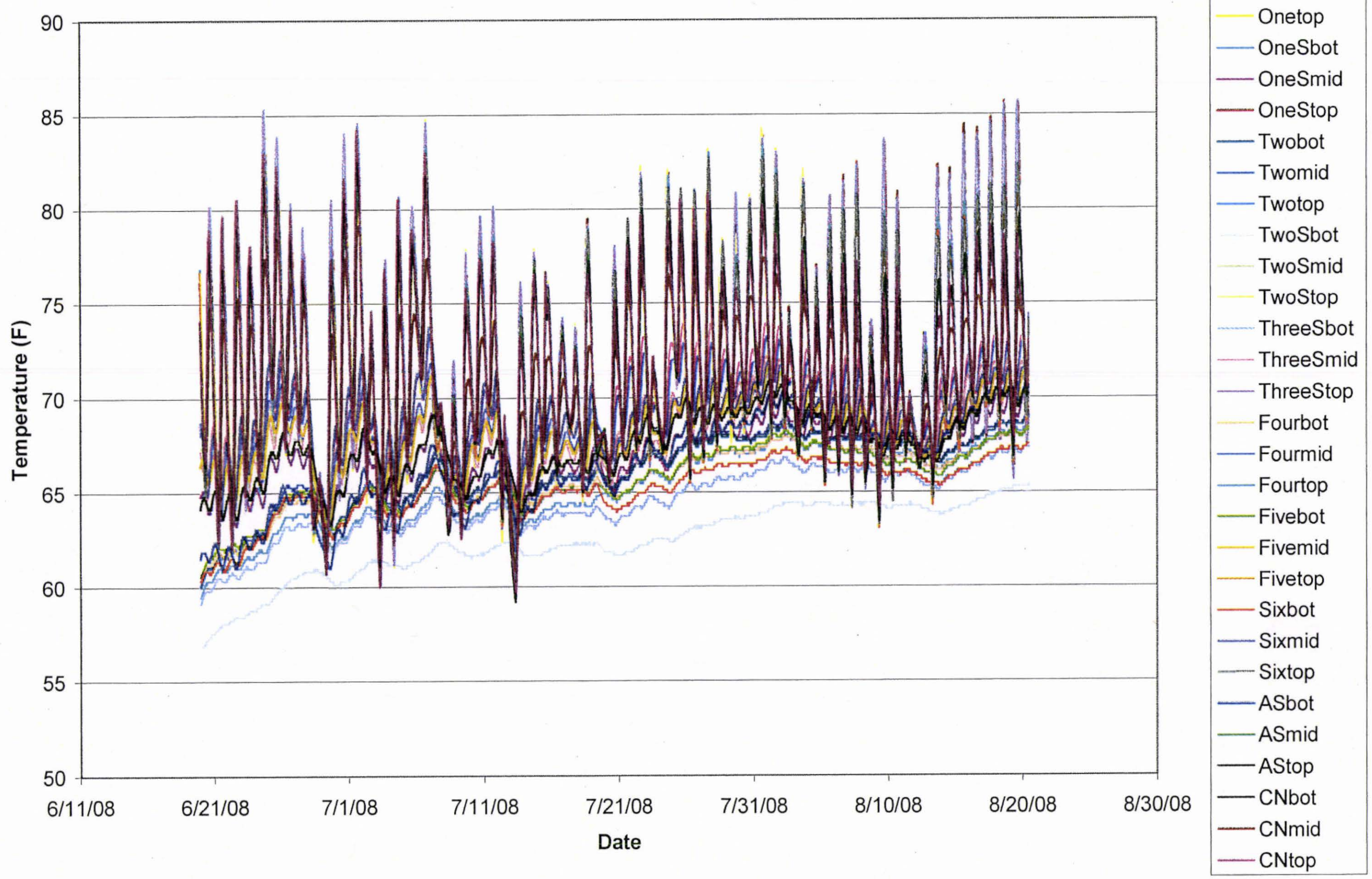


Location CN: May 18, 2008 - Nov 1, 2008
100
90
80
70
60
50
40
30
20
10
0
Temperature (F)
4/22/08
5/12/08
6/1/08
6/21/08
7/11/08
7/31/08
8/20/08
9/9/08
9/29/08
10/19/08
11/8/08
11/28/08
Date
CNbot
CNmid
CNtop

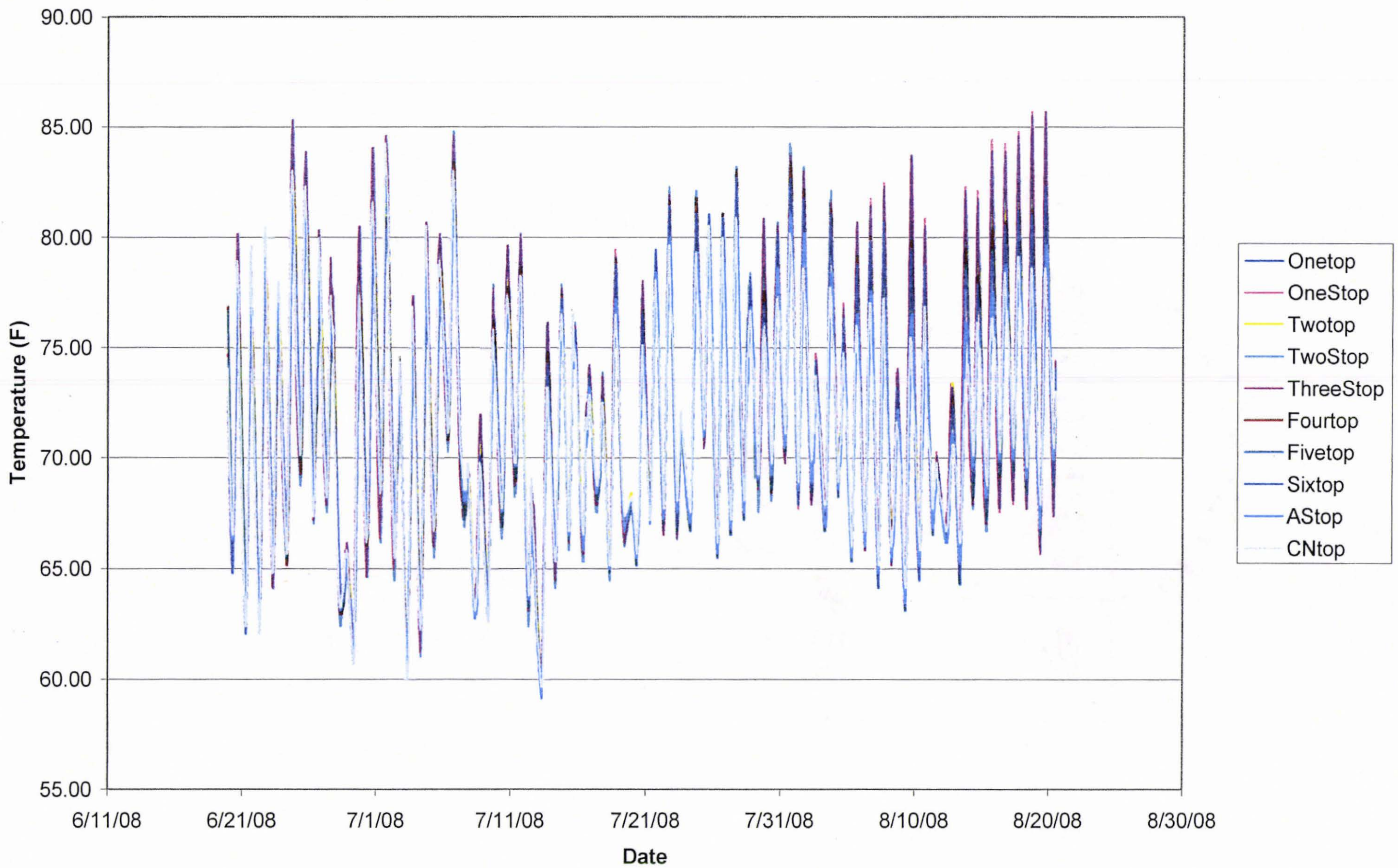
Appendix E

Temperature Profile Graphs – Summer Data Set

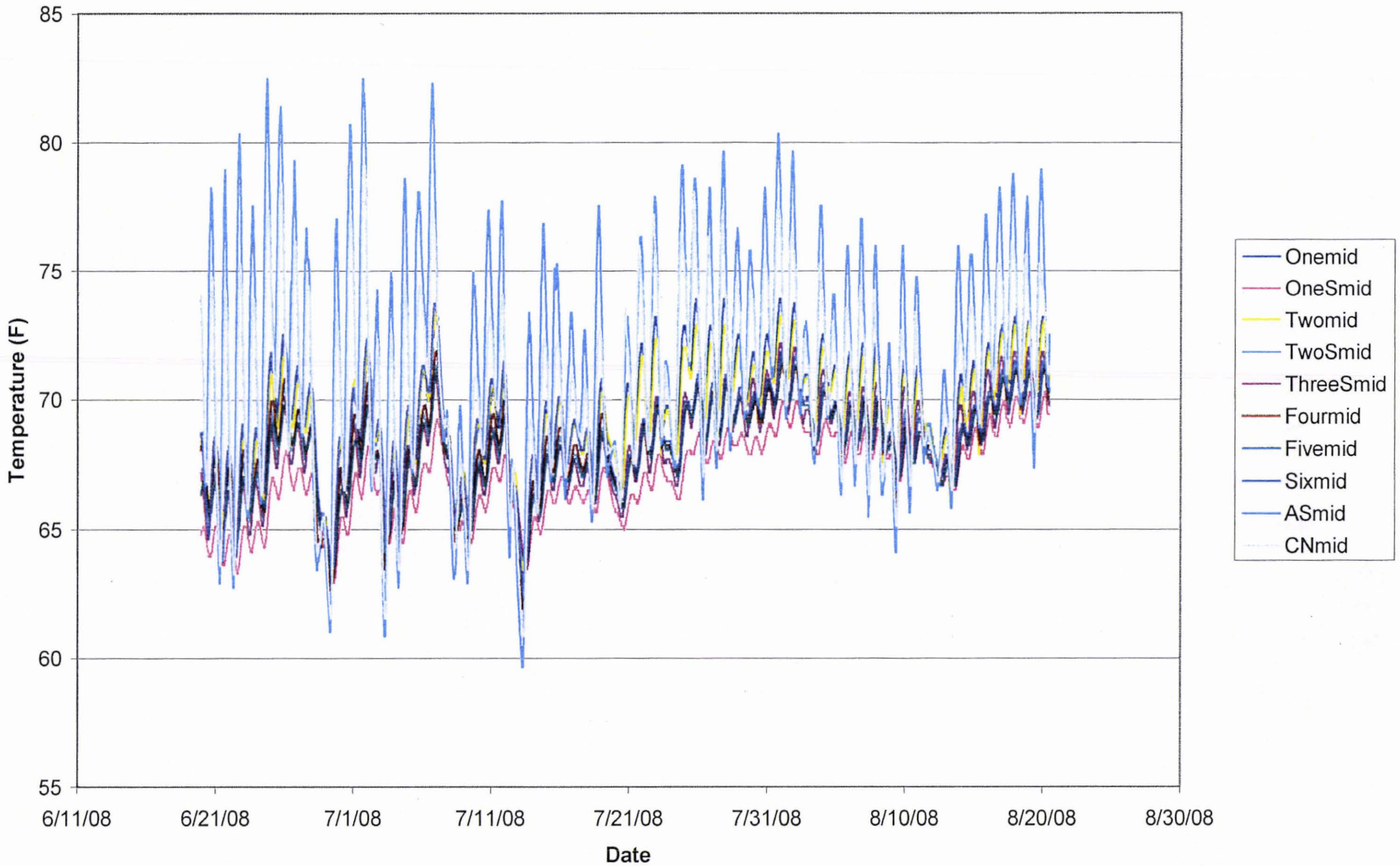
All Data: June 19, 2008 - August 20, 2008

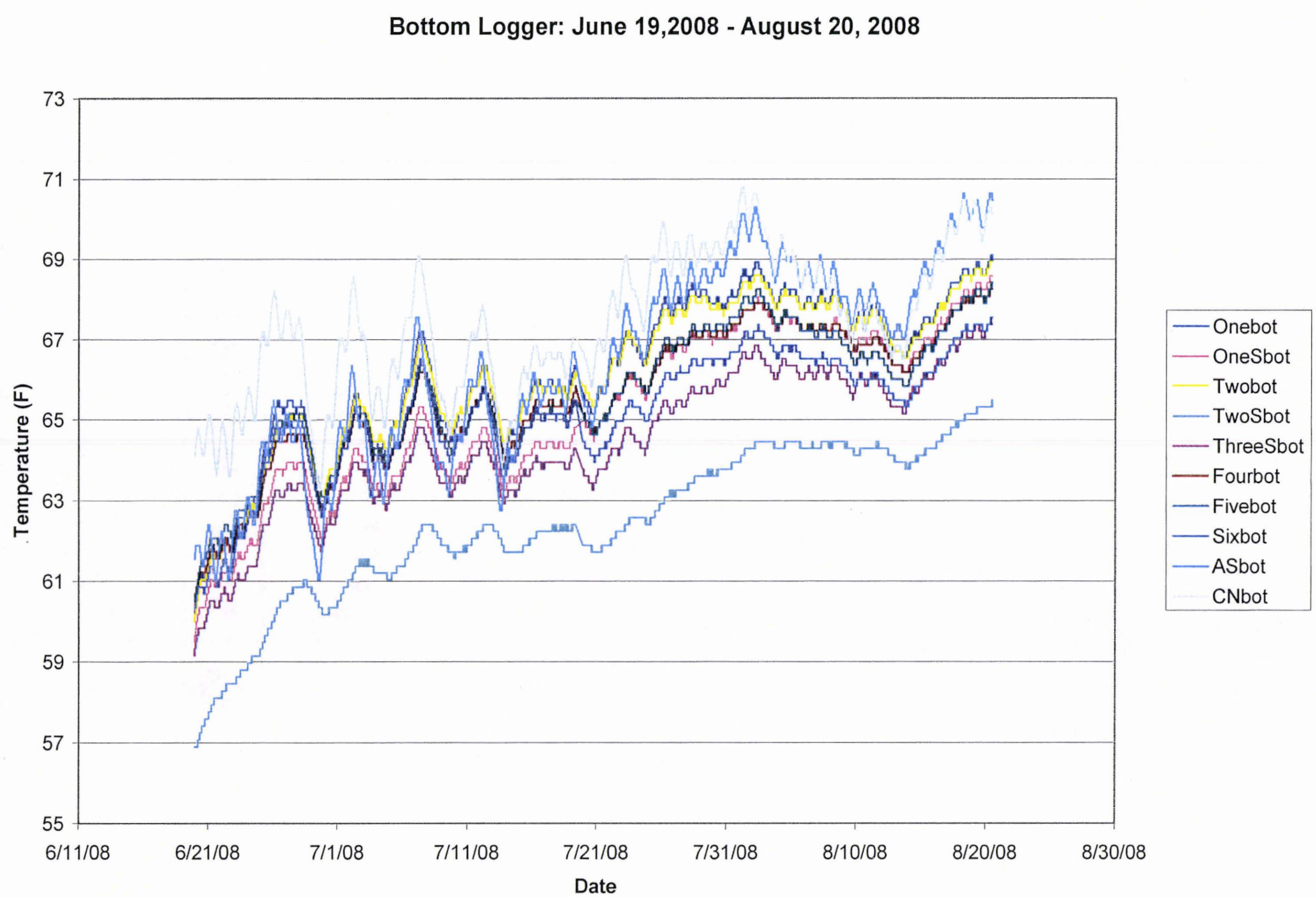


Top Logger: June 19,2008 - August 20, 2008

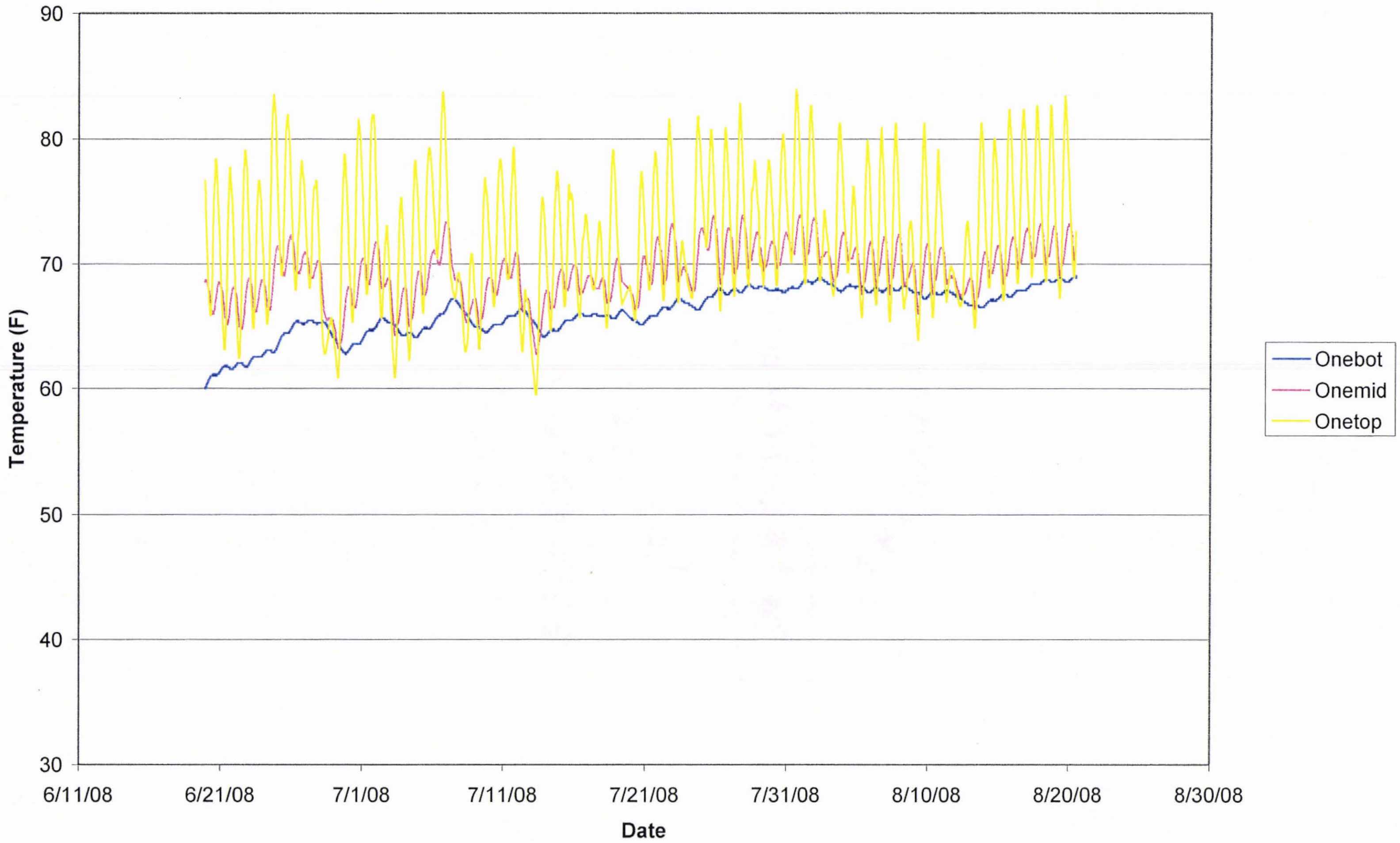


Middle Logger: June 19,2008 - August 20, 2008

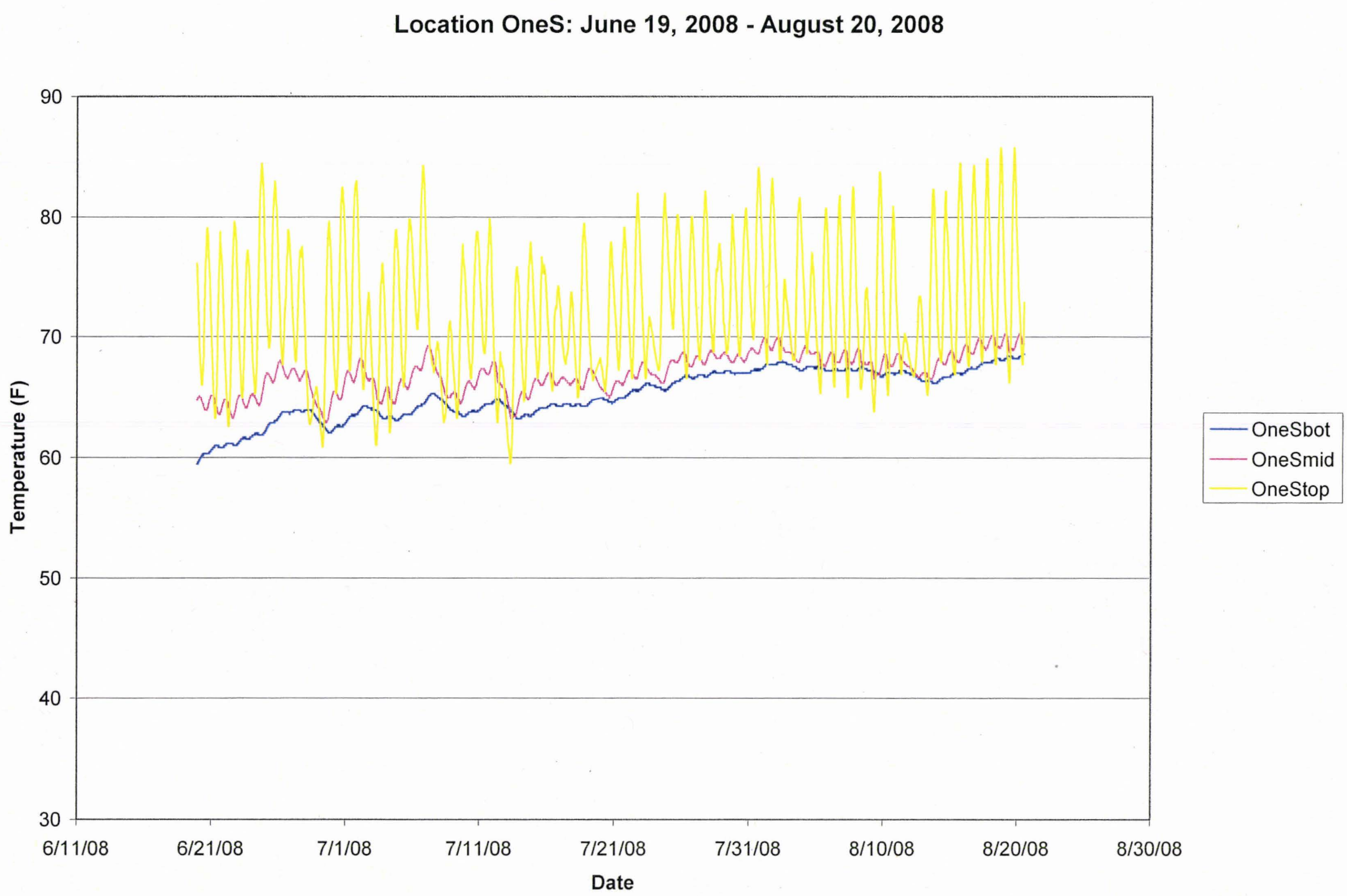



Bottom Logger: June 19,2008 - August 20, 2008
73
71
69
67
65
63
61
59
57
55
Temperature (F)
6/11/08
6/21/08
7/1/08
7/11/08
7/21/08
7/31/08
8/10/08
8/20/08
8/30/08
Date
Onebot
OneSbot
Twobot
TwoSbot
ThreeSbot
Fourbot
Fivebot
Sixbot
ASbot
CNbot

Location One: June 19, 2008 - August 20, 2008

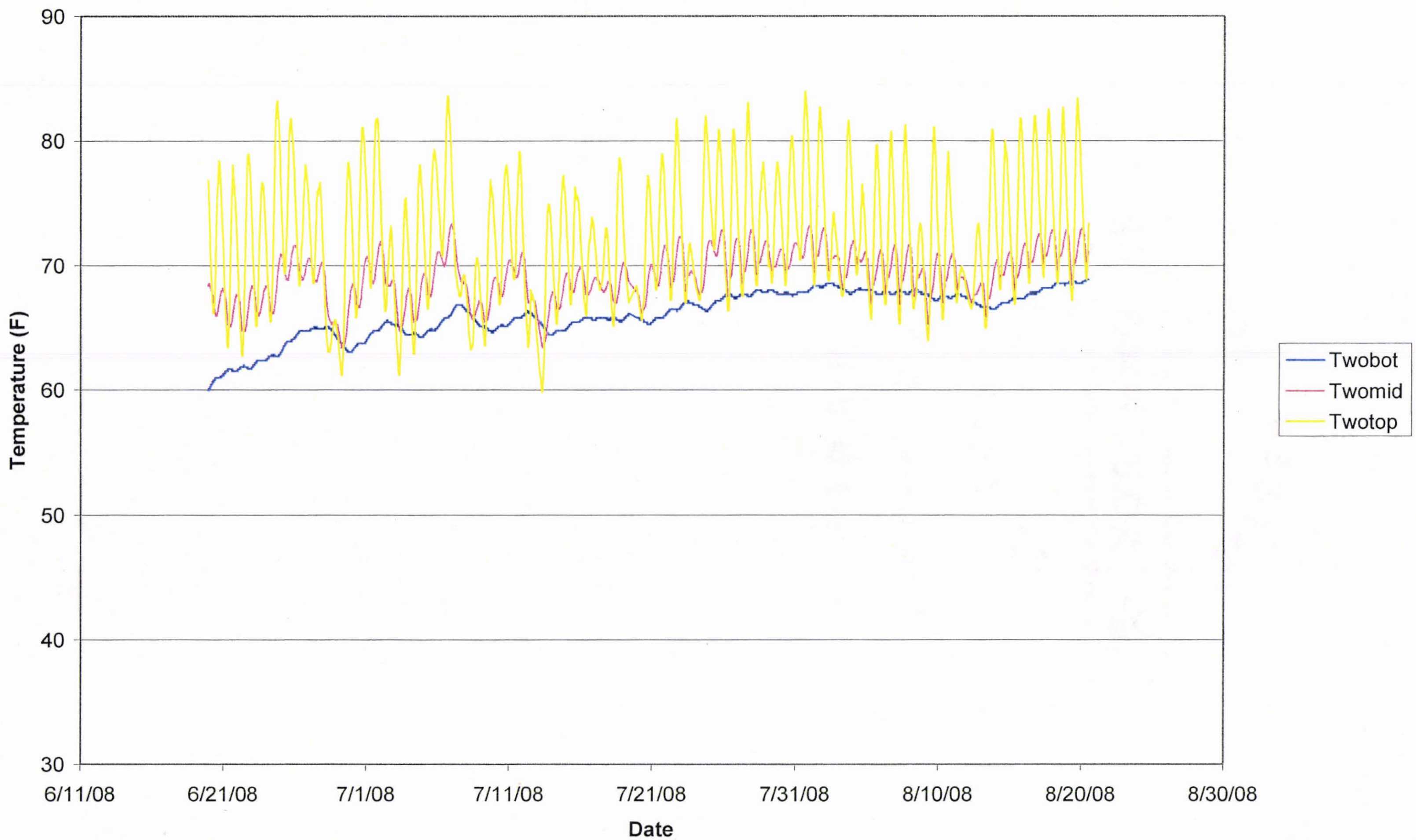


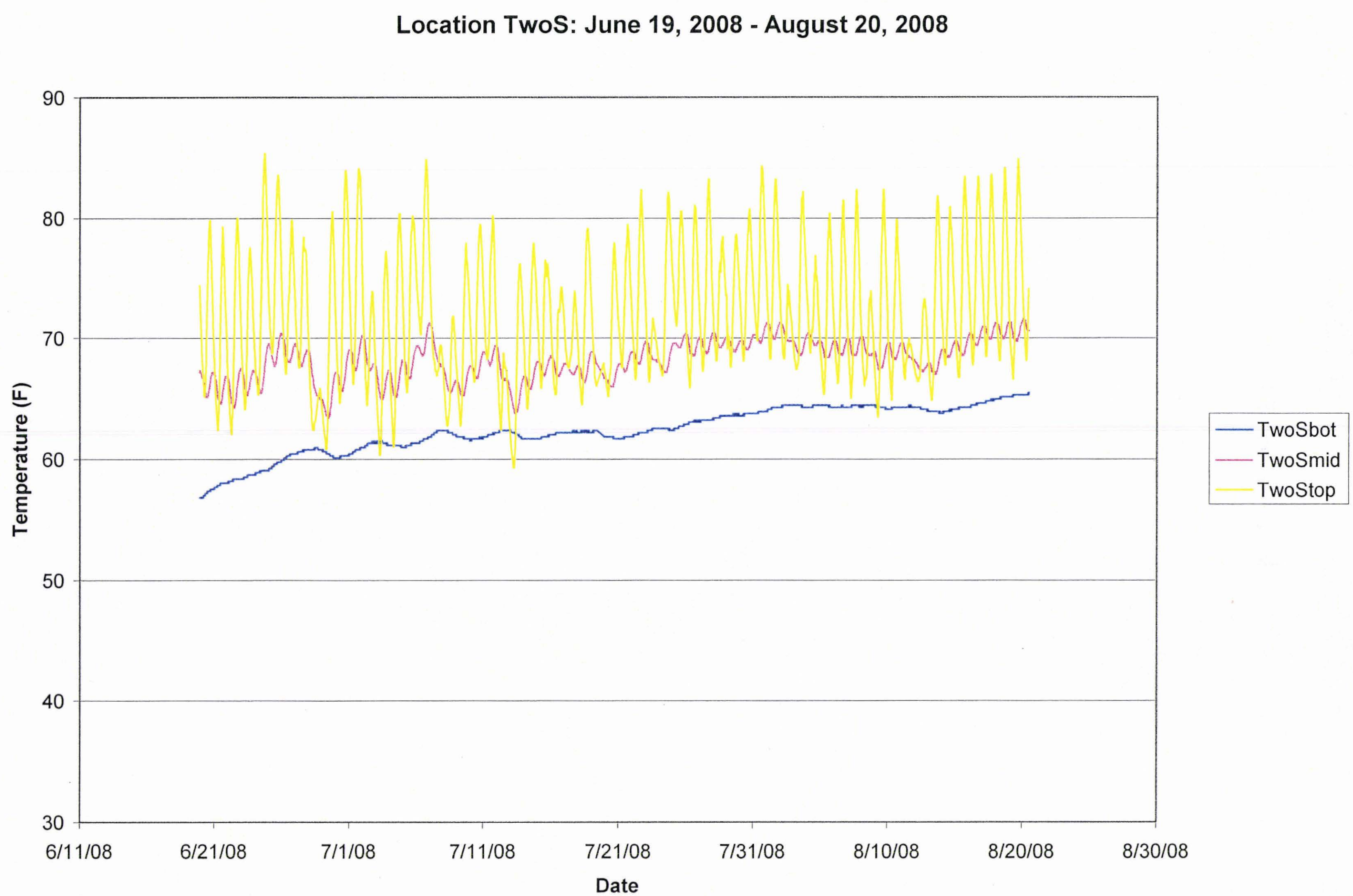
148



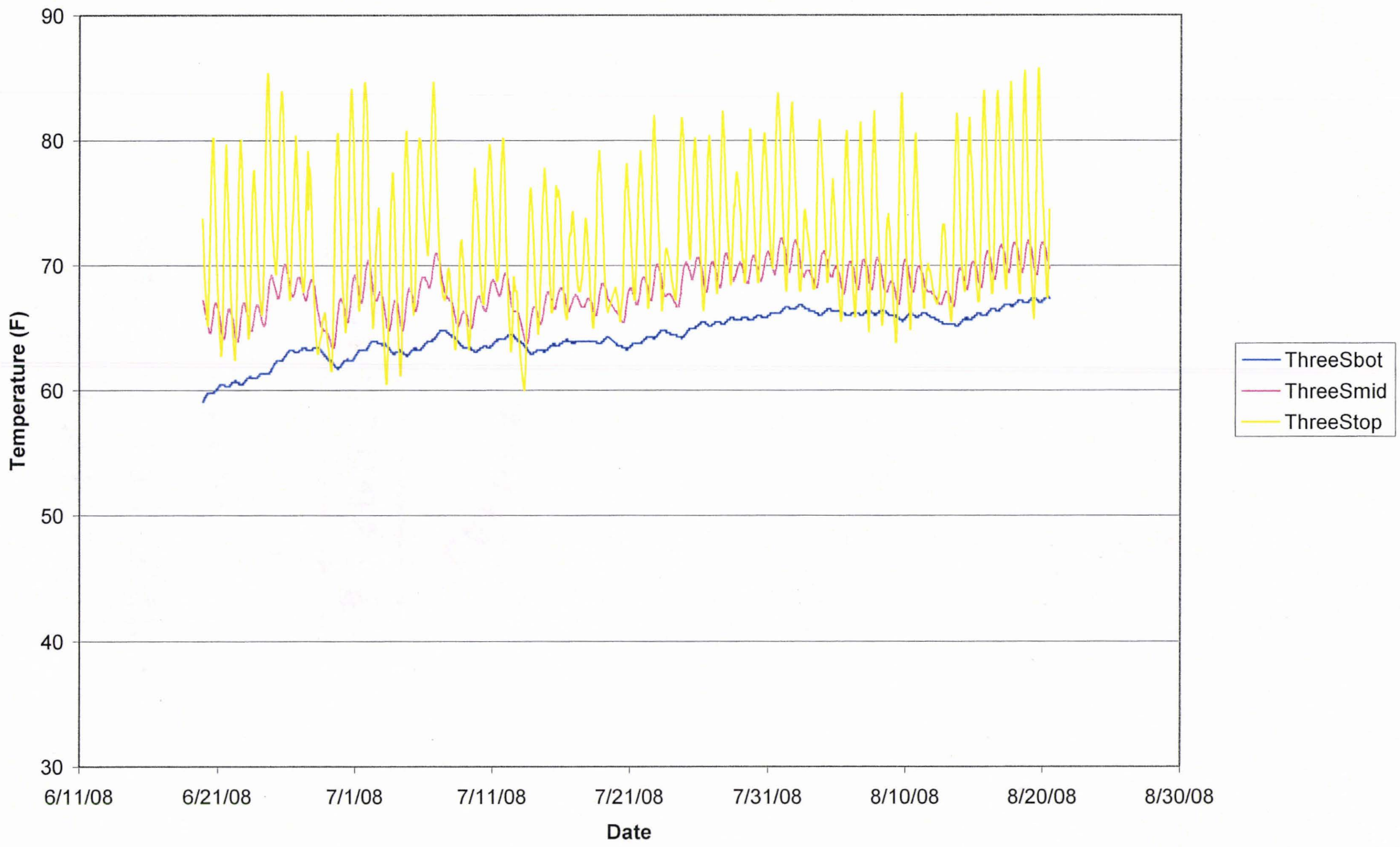
Location OneS: June 19, 2008 - August 20, 2008
90
80
70
60
50
40
30
Temperature (F)
6/11/08
6/21/08
7/1/08
7/11/08
7/21/08
7/31/08
8/10/08
8/20/08
8/30/08
Date
OneSbot
OneSmid
OneStop

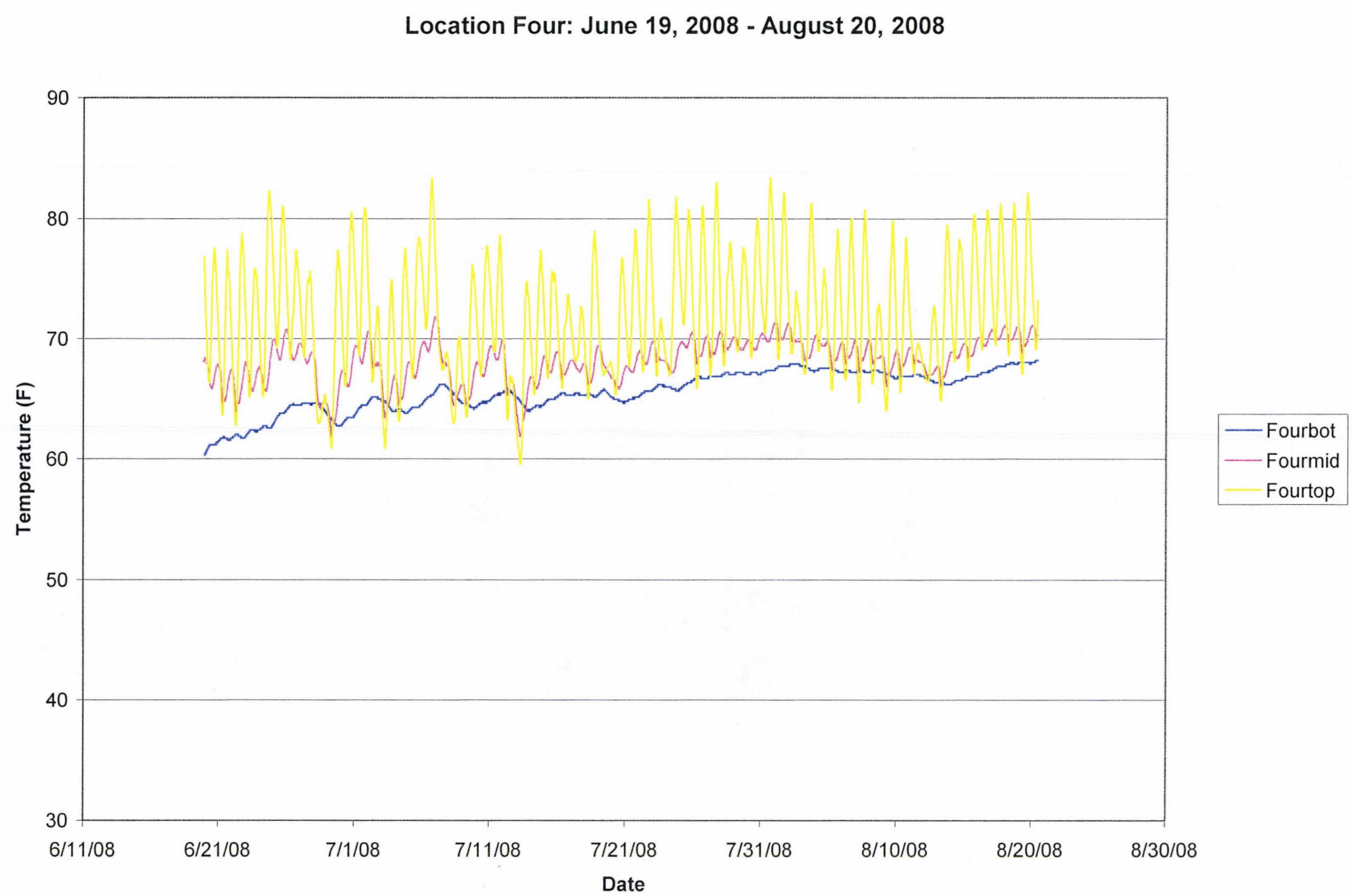
Location Two: June 19, 2008 - August 20, 2008



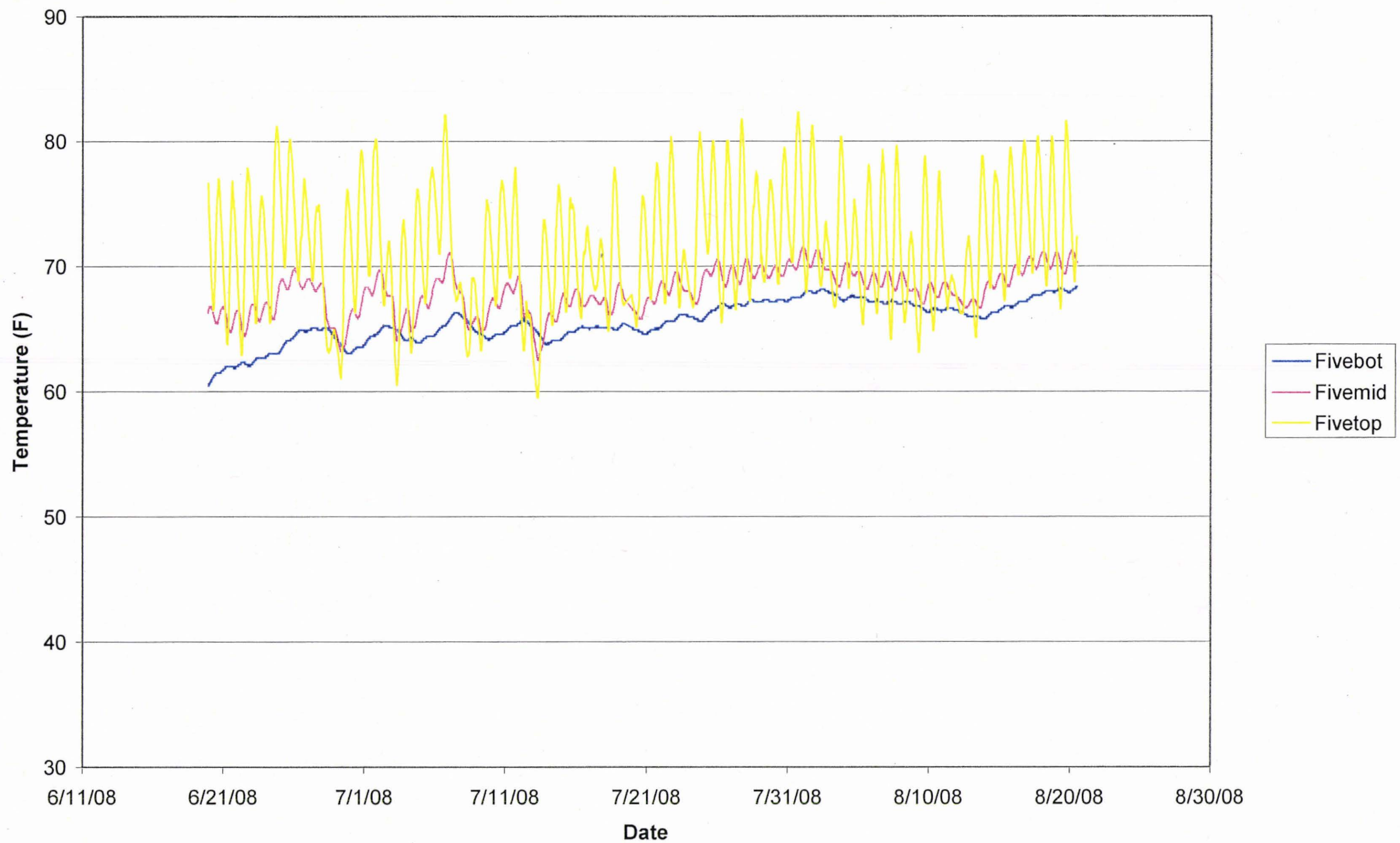

Location TwoS: June 19, 2008 - August 20, 2008
Temperature (F)
90
80
70
60
50
40
30
6/11/08
6/21/08
7/1/08
7/11/08
7/21/08
7/31/08
8/10/08
8/20/08
8/30/08
Date
TwoSbot
TwoSmid
TwoStop

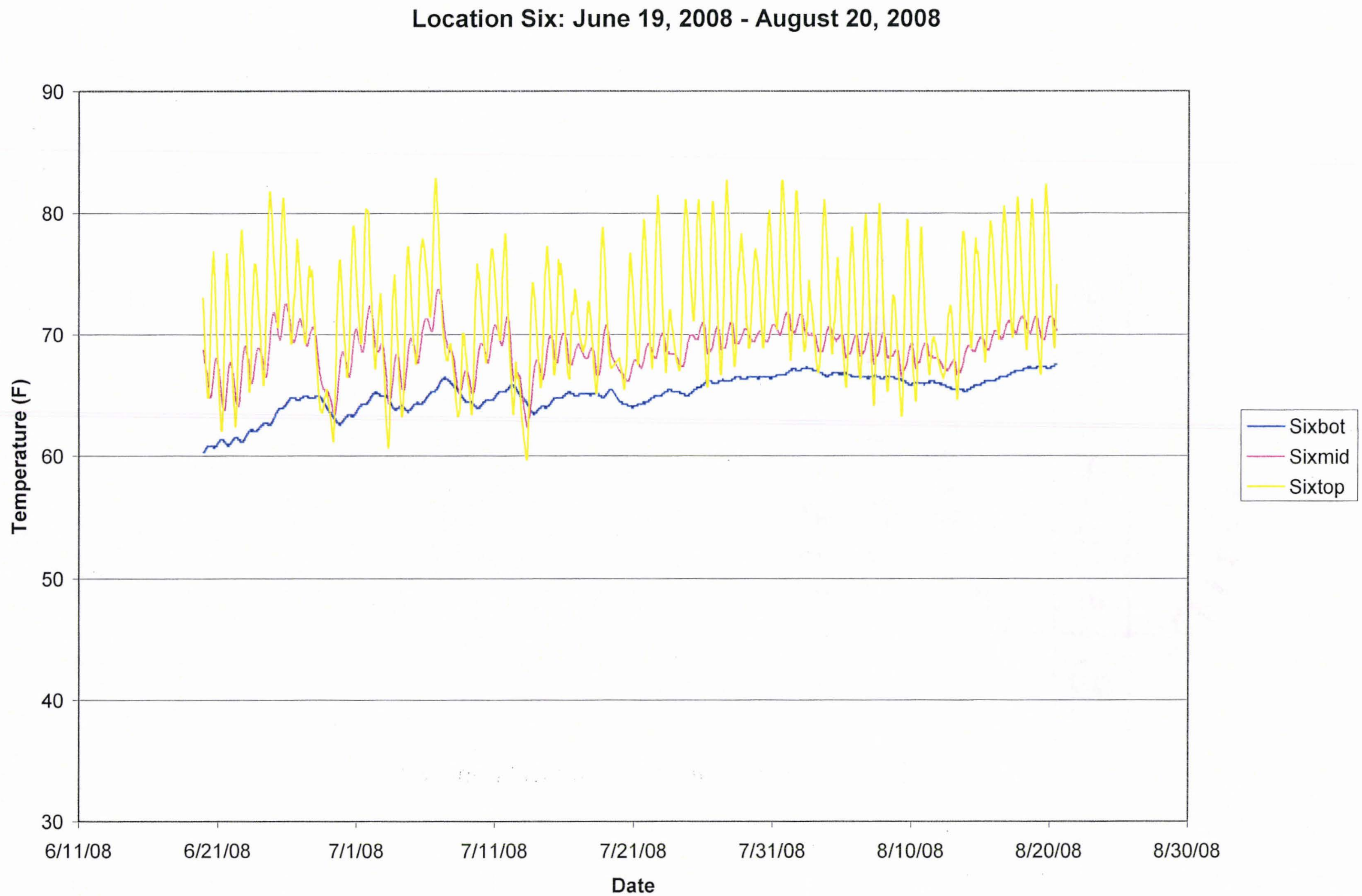
Location ThreeS: June 19, 2008 - August 20, 2008



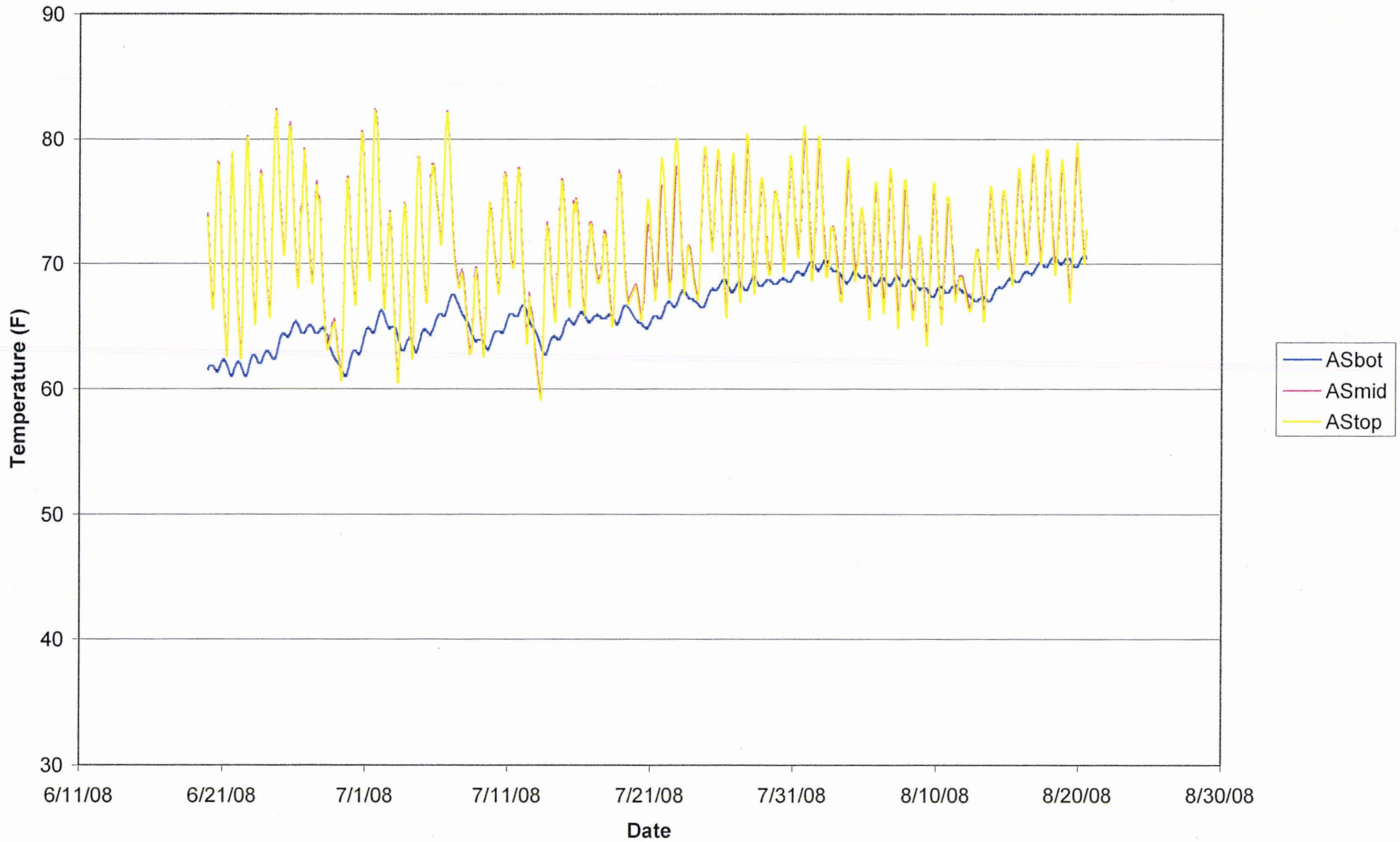

Location Four: June 19, 2008 - August 20, 2008
Temperature (F)
90
80
70
60
50
40
30
6/11/08
6/21/08
7/1/08
7/11/08
7/21/08
7/31/08
8/10/08
8/20/08
8/30/08
Date
Fourbot
Fourmid
Fourtop

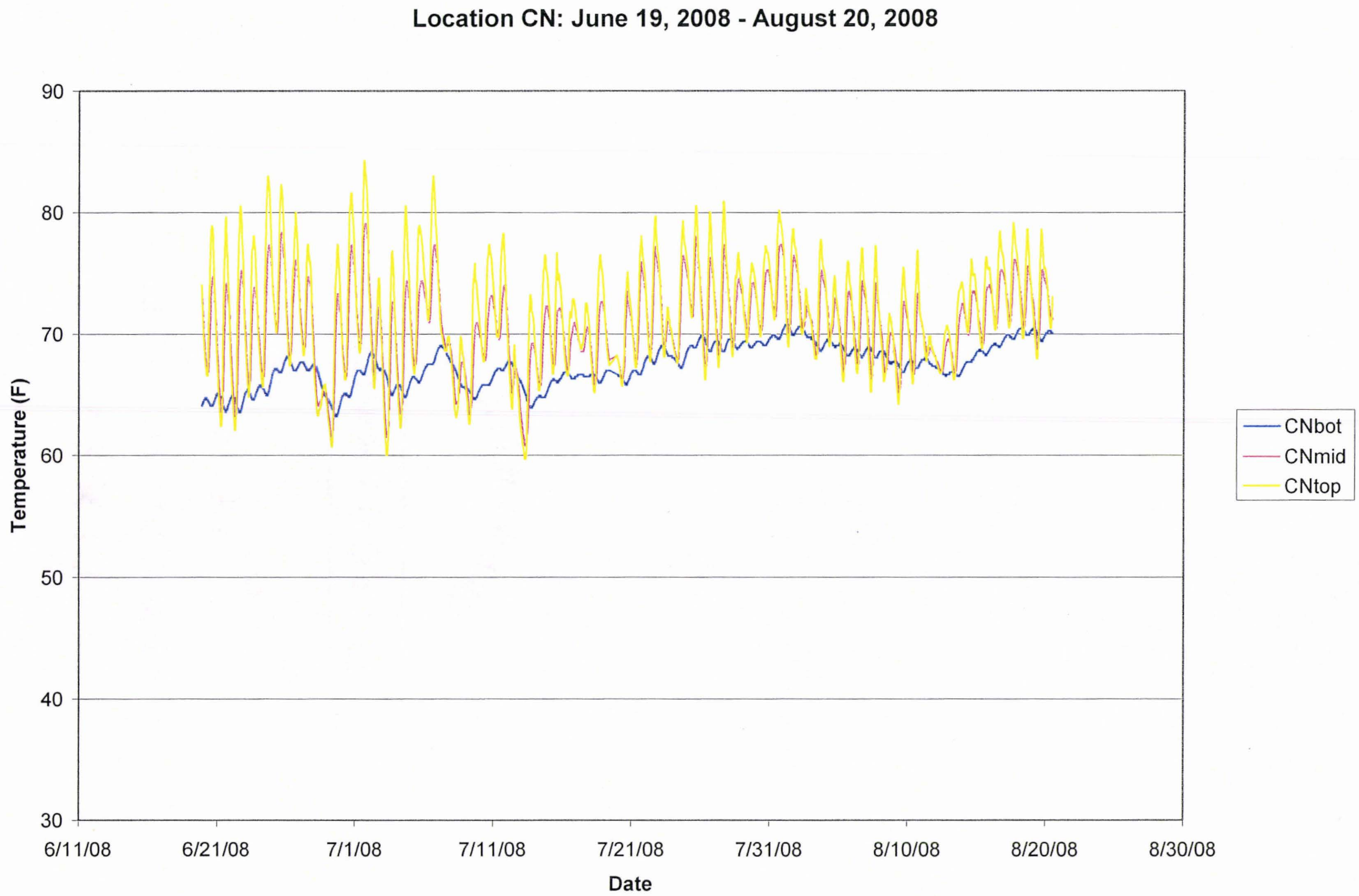
Location Five: June 19, 2008 - August 20, 2008




Location Six: June 19, 2008 - August 20, 2008
90
80
70
60
50
40
30
Temperature (F)
6/11/08
6/21/08
7/1/08
7/11/08
7/21/08
7/31/08
8/10/08
8/20/08
8/30/08
Date
Sixbot
Sixmid
Sixtop

Location AS: June 19, 2008 - August 20, 2008

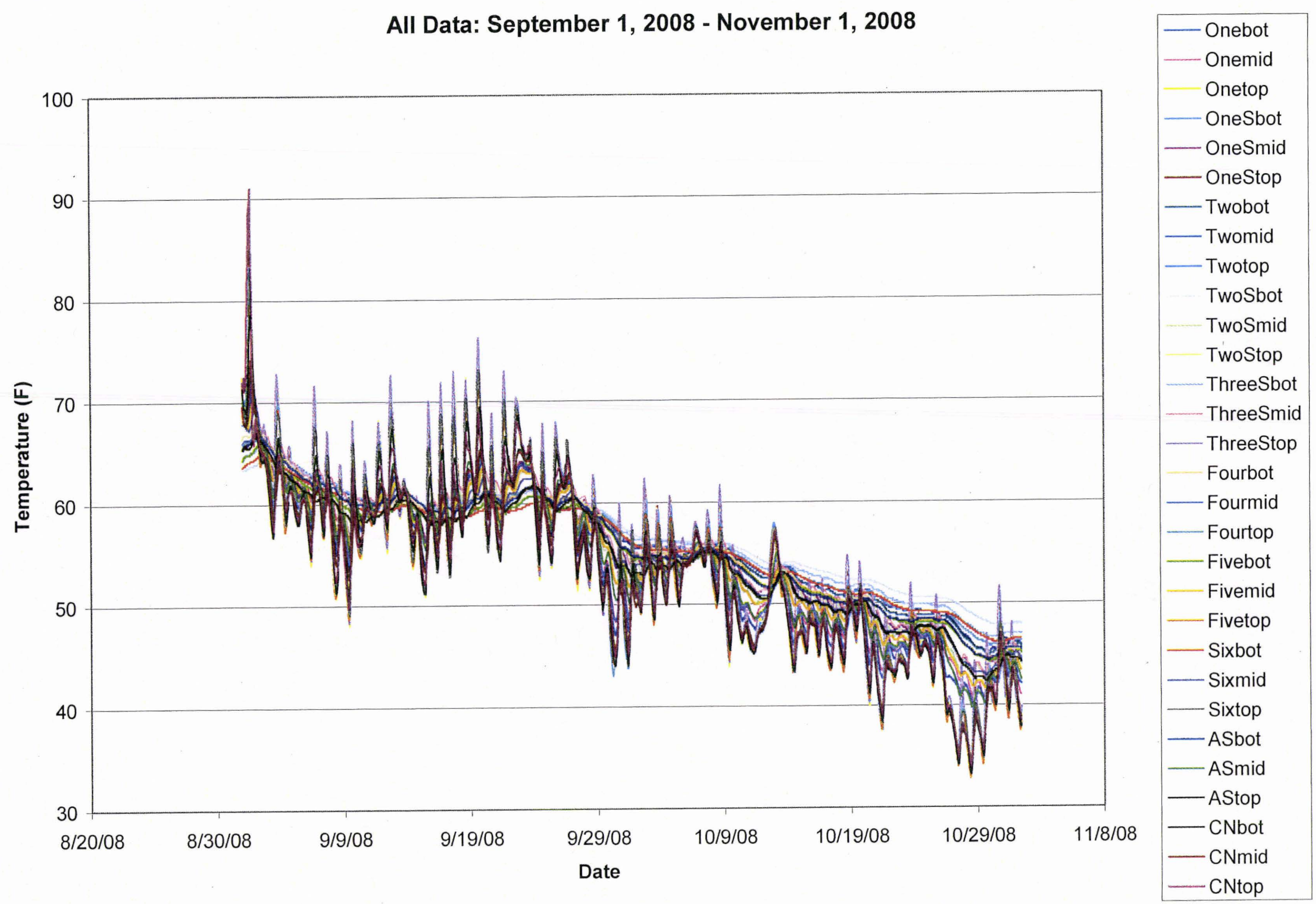


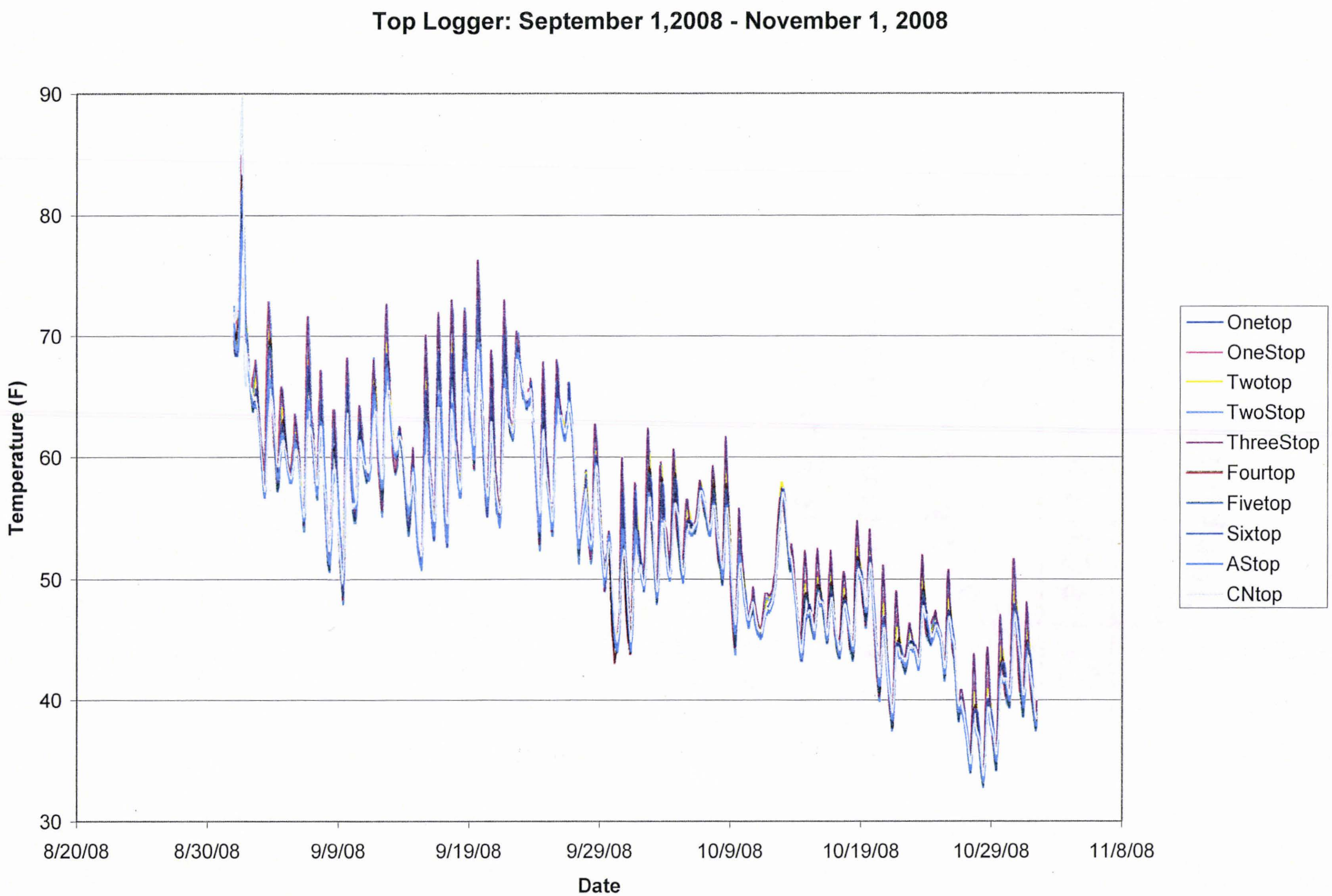


Location CN: June 19, 2008 - August 20, 2008
90
80
70
60
50
40
30
Temperature (F)
6/11/08
6/21/08
7/1/08
7/11/08
7/21/08
7/31/08
8/10/08
8/20/08
8/30/08
Date
CNbot
CNmid
CNtop

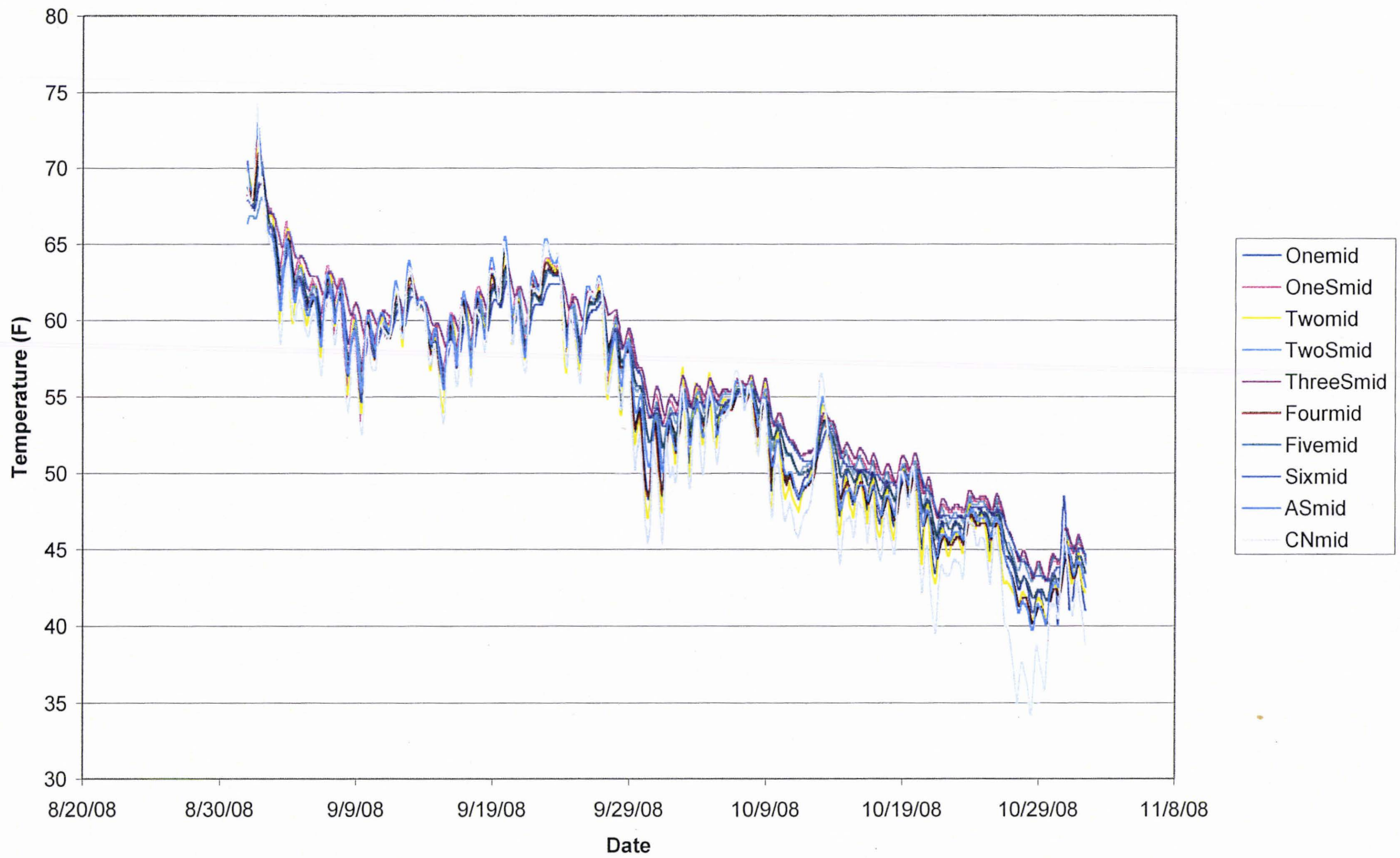
Appendix F

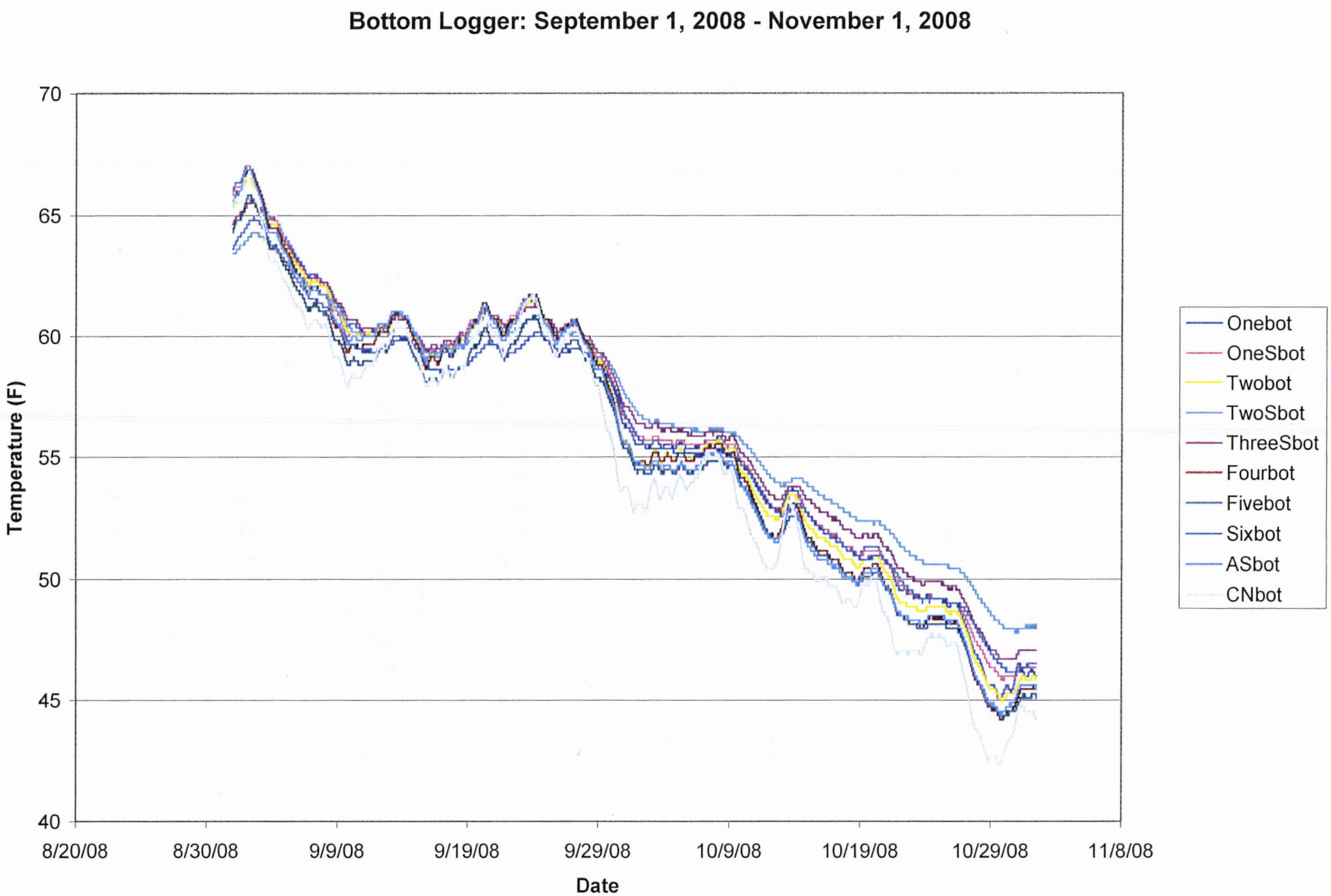
Temperature Profile Graphs - Fall Data Set


All Data: September 1, 2008 - November 1, 2008
Temperature (F)
100
90
80
70
60
50
40
30
8/20/08
8/30/08
9/9/08
9/19/08
9/29/08
10/9/08
10/19/08
10/29/08
11/8/08
Date
Onebot
Onemid
Onetop
OneSbot
OneSmid
OneStop
Twobot
Twomid
Twotop
TwoSbot
TwoSmid
TwoStop
ThreeSbot
ThreeSmid
ThreeStop
Fourbot
Fourmid
Fourtop
Fivebot
Fivemid
Fivetop
Sixbot
Sixmid
Sixtop
ASbot
ASmid
AStop
CNbot
CNmid
CNtop

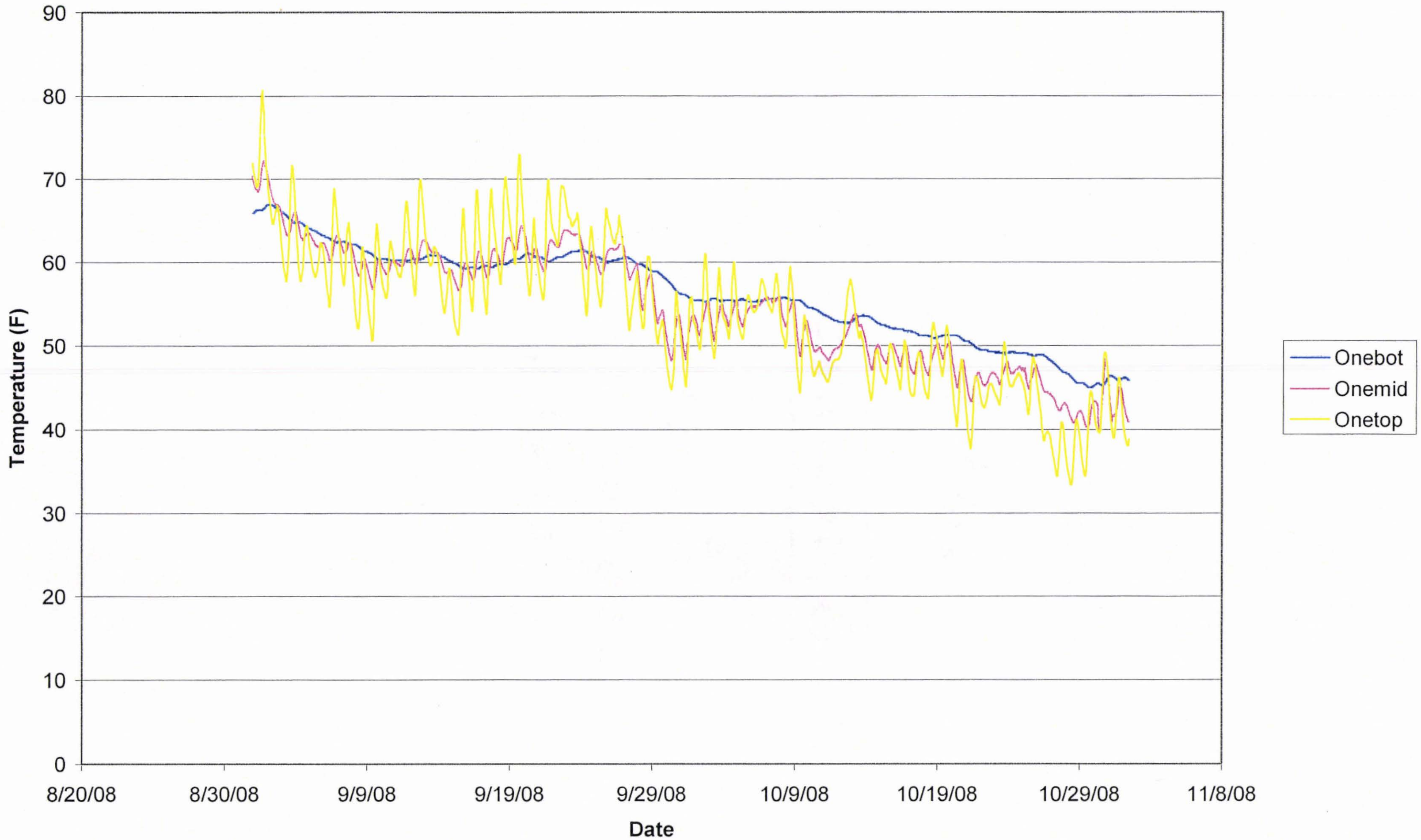

Top Logger: September 1,2008 - November 1, 2008
Temperature (F)
90
80
70
60
50
40
30
8/20/08
8/30/08
9/9/08
9/19/08
9/29/08
10/9/08
10/19/08
10/29/08
11/8/08
Date
Onetop
OneStop
Twotop
TwoStop
ThreeStop
Fourtop
Fivetop
Sixtop
AStop
CNtop

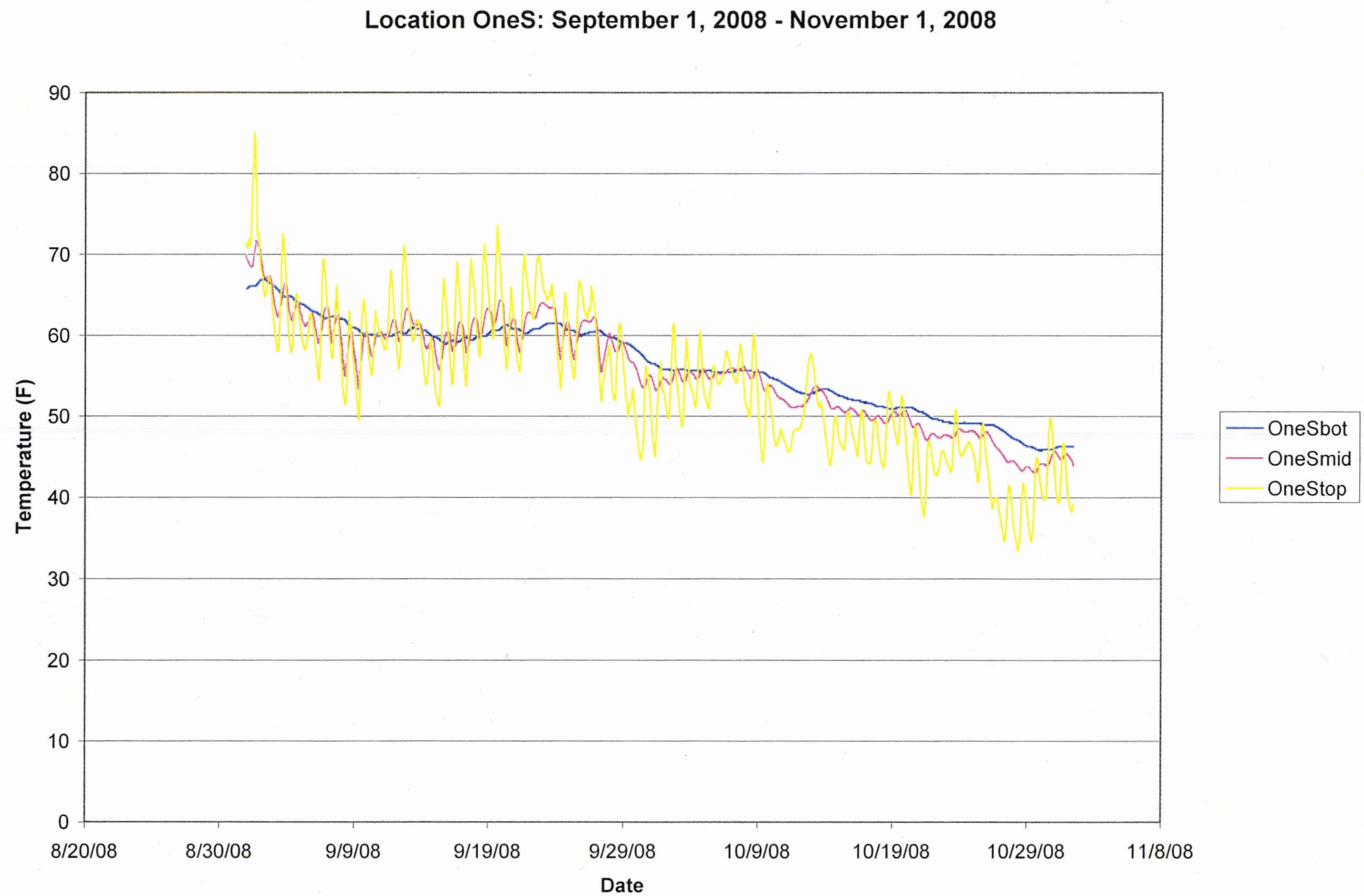
Middle Logger: September 1,2008 - November 1, 2008



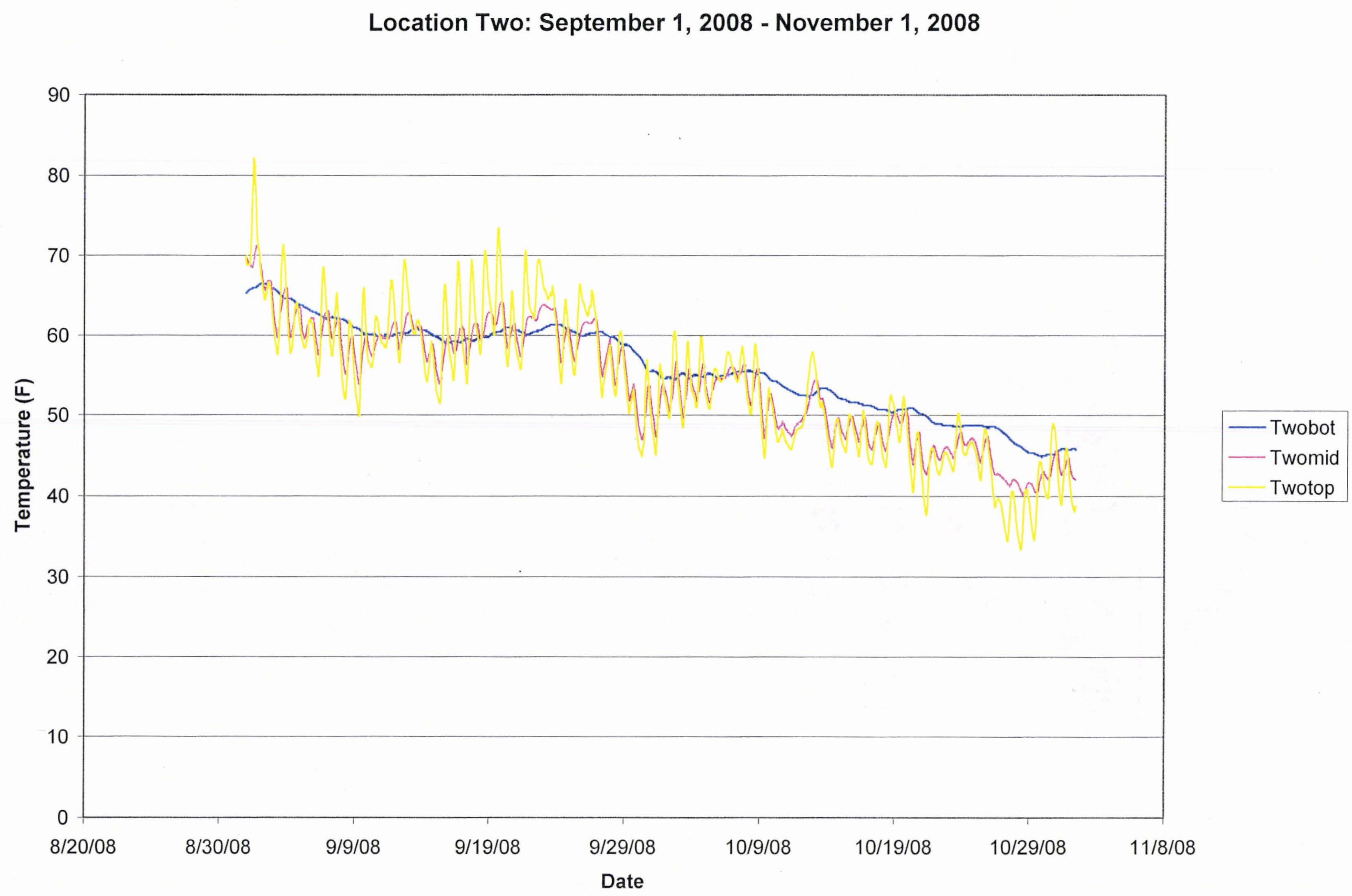

Bottom Logger: September 1, 2008 - November 1, 2008
70
65
60
55
50
45
40
Temperature (F)
8/20/08
8/30/08
9/9/08
9/19/08
9/29/08
10/9/08
10/19/08
10/29/08
11/8/08
Date
Onebot
OneSbot
Twobot
TwoSbot
ThreeSbot
Fourbot
Fivebot
Sixbot
ASbot
CNbot

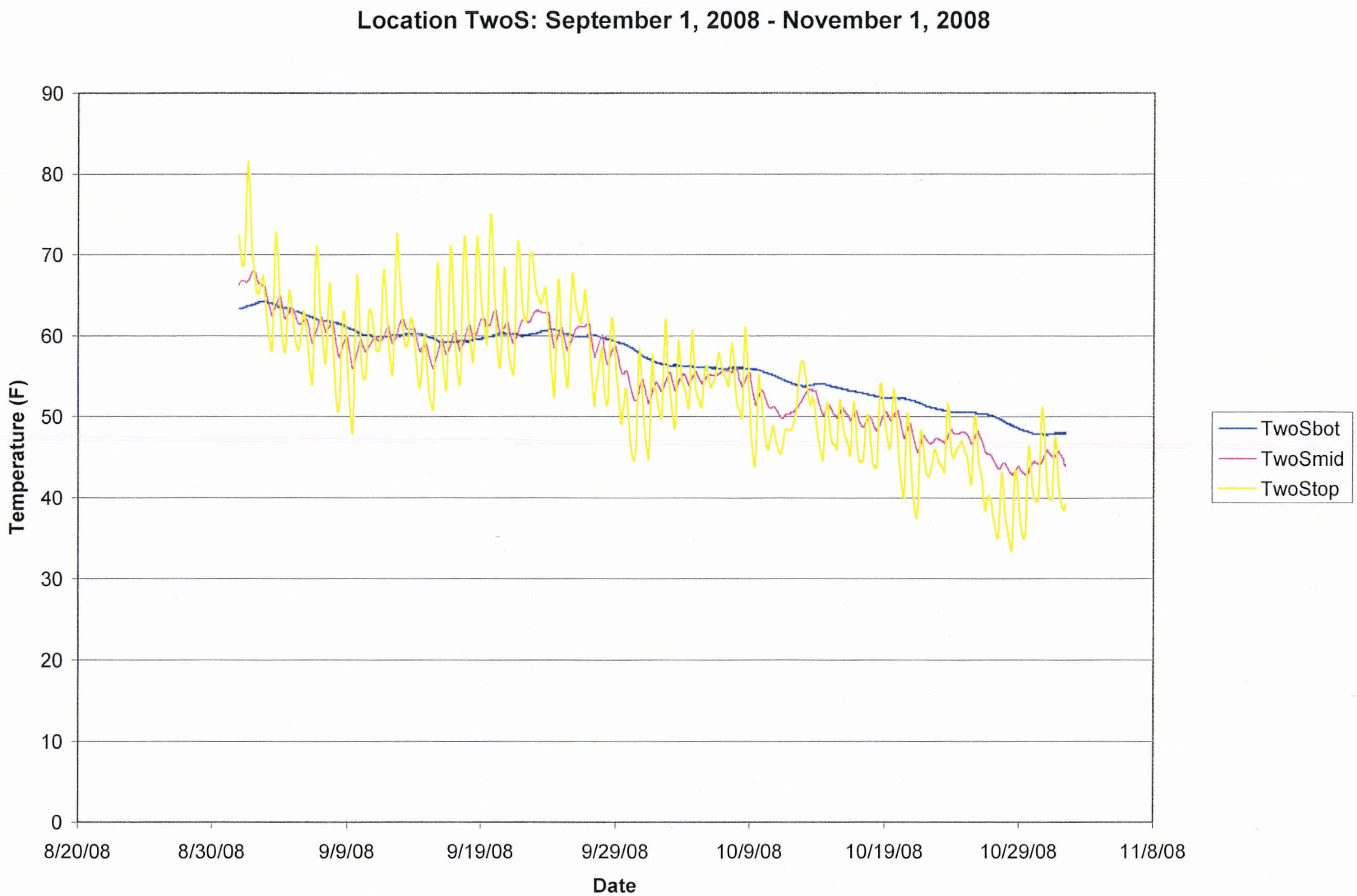
Location One: September 1, 2008 - November 1, 2008



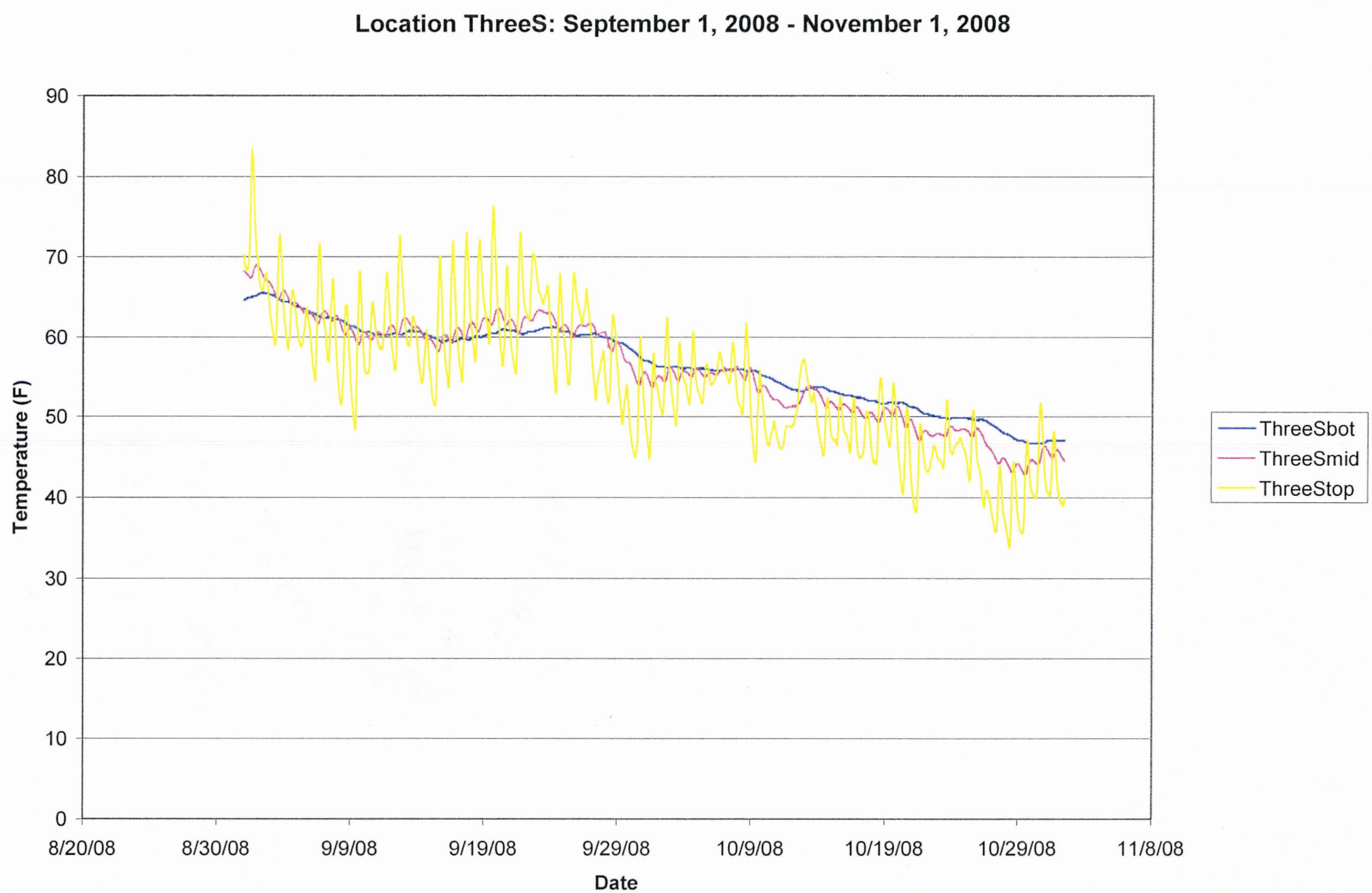


Location OneS: September 1, 2008 - November 1, 2008
Temperature (F)
90
80
70
60
50
40
30
20
10
0
8/20/08
8/30/08
9/9/08
9/19/08
9/29/08
10/9/08
10/19/08
10/29/08
11/8/08
Date
OneSbot
OneSmid
OneStop


Location Two: September 1, 2008 - November 1, 2008
Temperature (F)
90
80
70
60
50
40
30
20
10
0
8/20/08
8/30/08
9/9/08
9/19/08
9/29/08
10/9/08
10/19/08
10/29/08
11/8/08
Date
Twobot
Twomid
Twotop

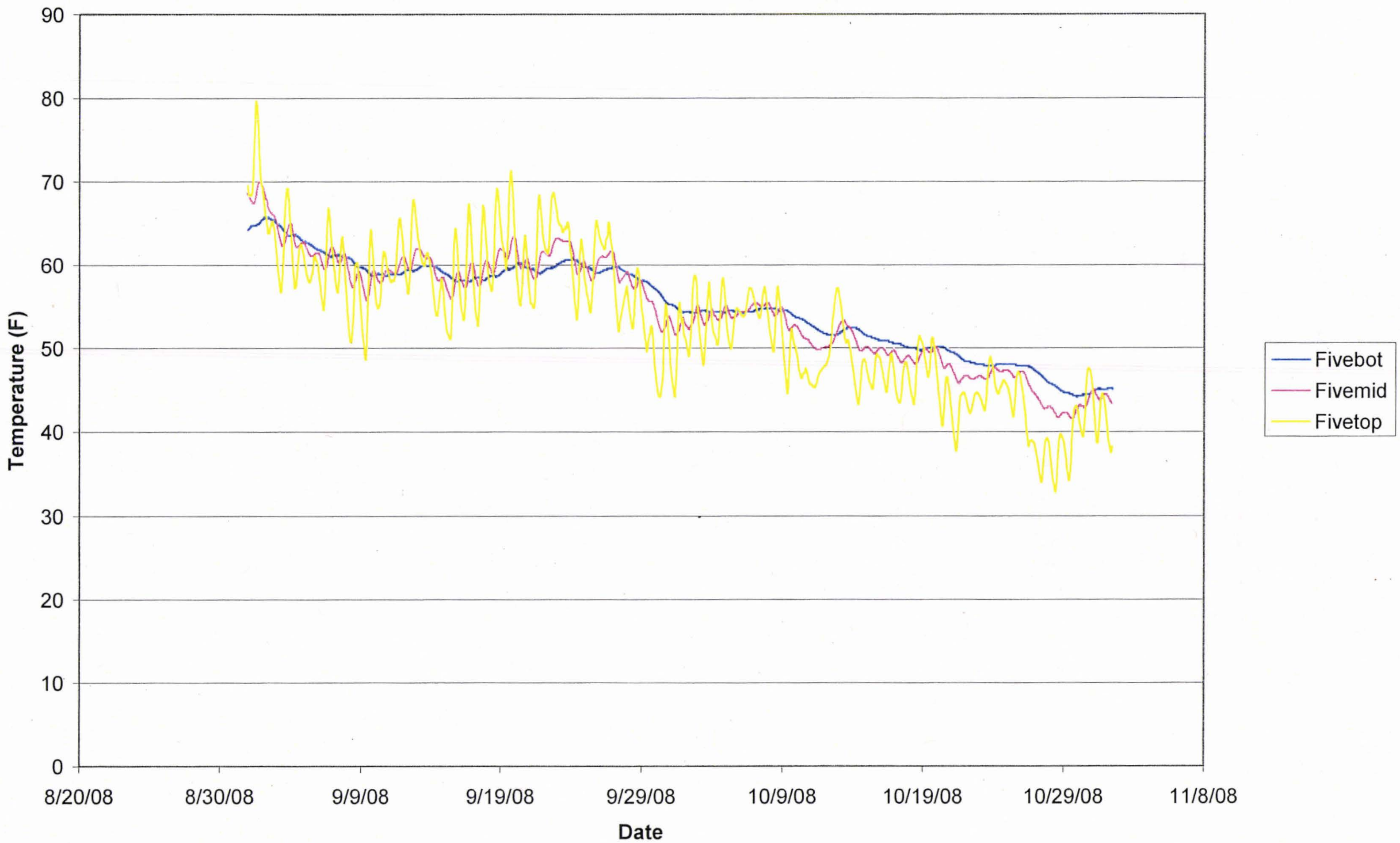


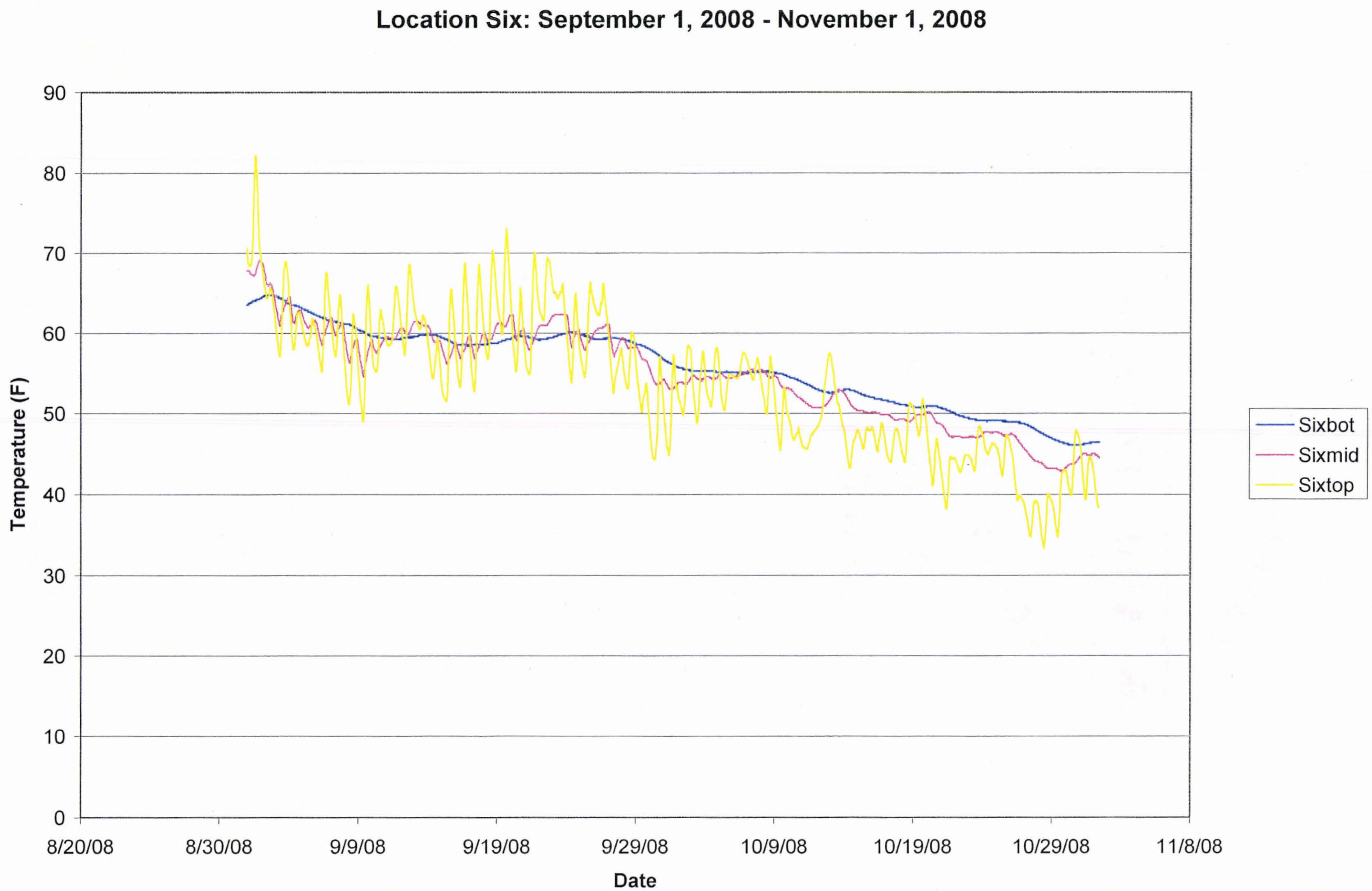
Location TwoS: September 1, 2008 - November 1, 2008
Temperature (F)
90
80
70
60
50
40
30
20
10
0
8/20/08
8/30/08
9/9/08
9/19/08
9/29/08
10/9/08
10/19/08
10/29/08
11/8/08
Date
TwoSbot
TwoSmid
TwoStop

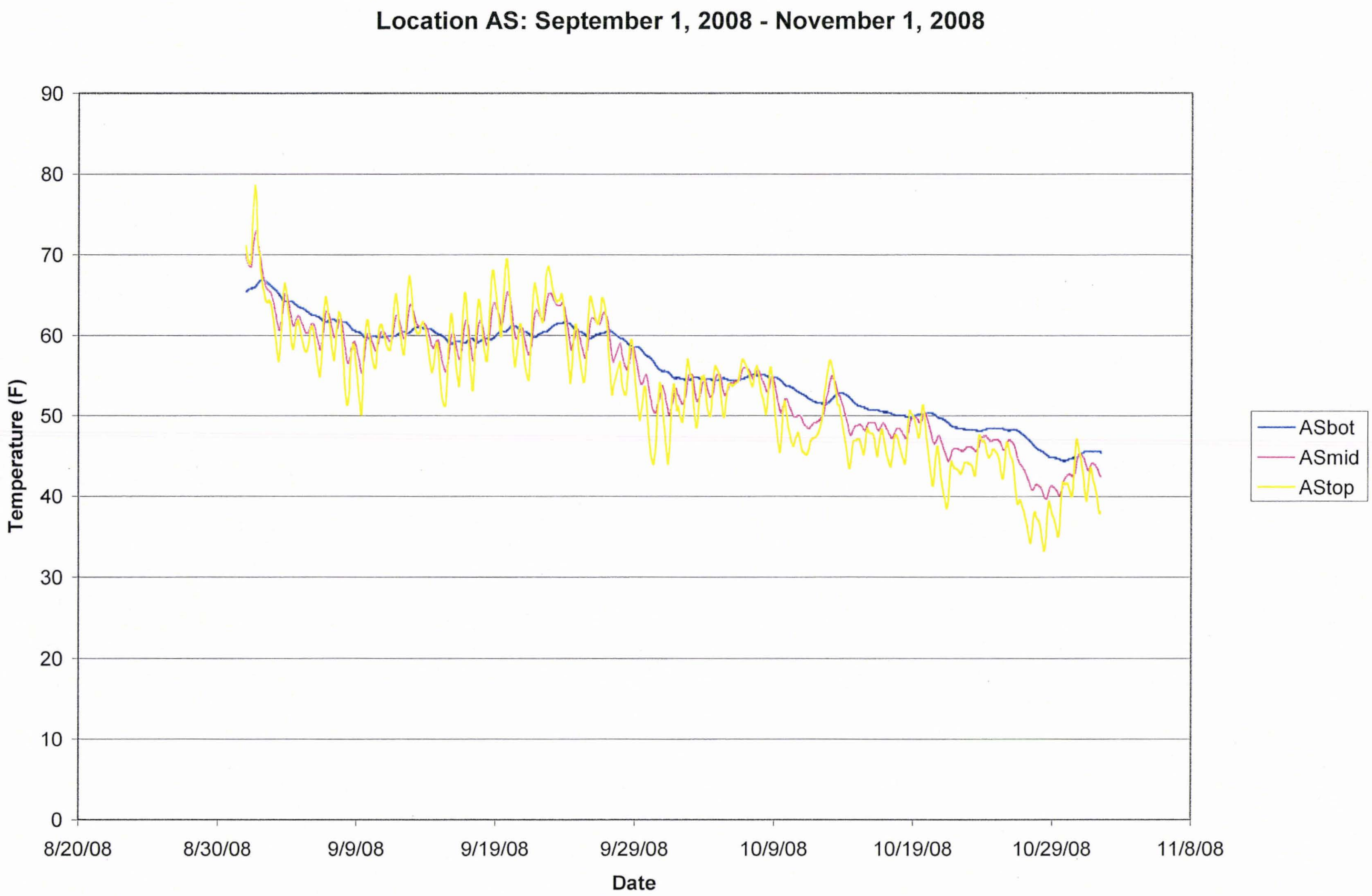

Location ThreeS: September 1, 2008 - November 1, 2008
Temperature (F)
90
80
70
60
50
40
30
20
10
0
8/20/08
8/30/08
9/9/08
9/19/08
9/29/08
10/9/08
10/19/08
10/29/08
11/8/08
Date
ThreeSbot
ThreeSmid
ThreeStop

Location Four: September 1, 2008 - November 1, 2008

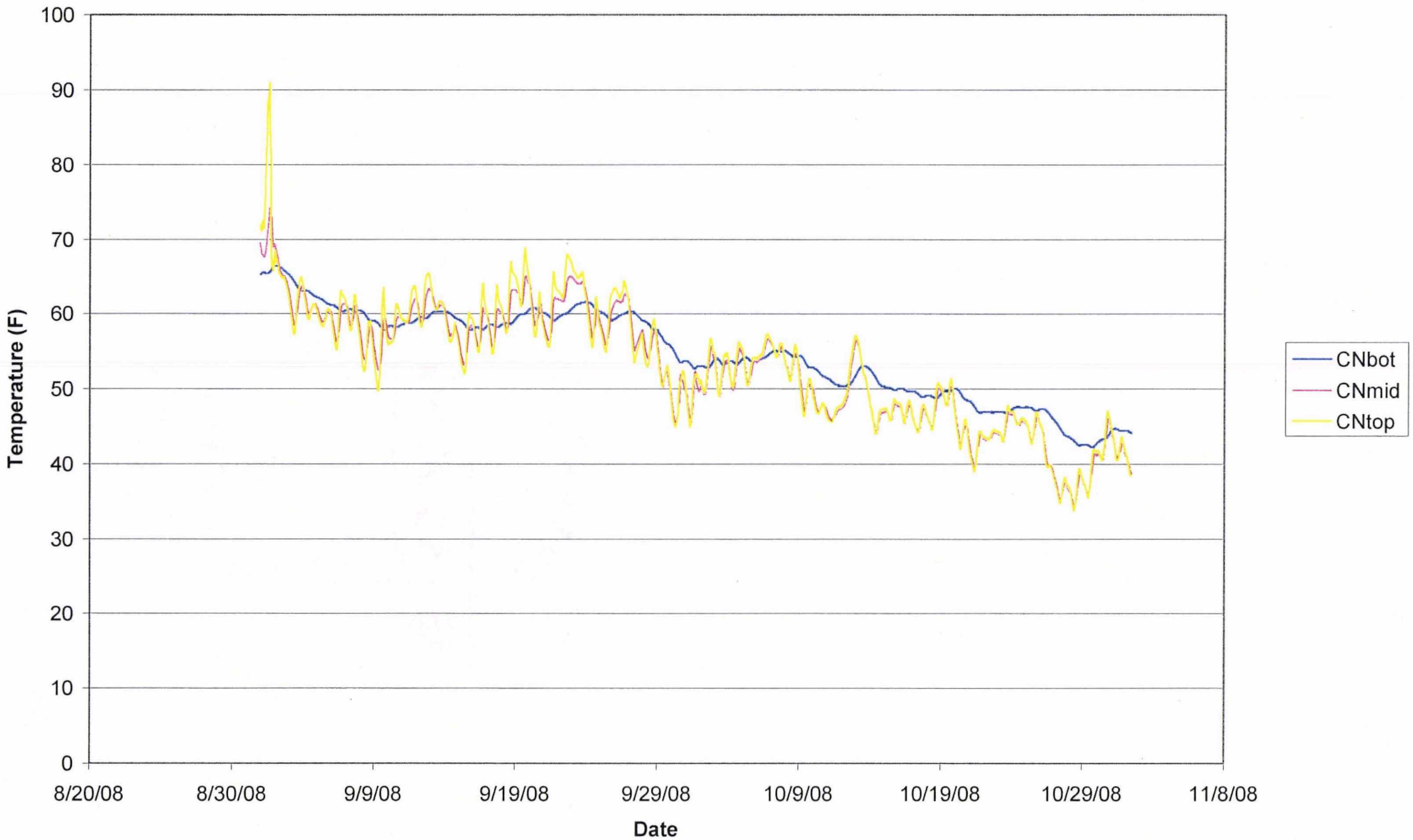
Location Five: September 1, 2008 - November 1, 2008




Location Six: September 1, 2008 - November 1, 2008
90
80
70
60
50
40
30
20
10
0
Temperature (F)
8/20/08
8/30/08
9/9/08
9/19/08
9/29/08
10/9/08
10/19/08
10/29/08
11/8/08
Date
Sixbot
Sixmid
Sixtop


Location AS: September 1, 2008 - November 1, 2008
Temperature (F)
90
80
70
60
50
40
30
20
10
0
8/20/08
8/30/08
9/9/08
9/19/08
9/29/08
10/9/08
10/19/08
10/29/08
11/8/08
Date
ASbot
ASmid
AStop

Location CN: September 1, 2008 - November 1, 2008



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